FUNCTIONAL SUCCESS OF SIX CONSTRUCTED BOTTOMLAND HARDWOOD FORESTS IN CENTRAL AND WESTERN KENTUCKY

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Wetland construction and restoration has rapidly increased in the past decade --mainly due to state and federal mandates. Because all wetland restoration and creation efforts have the goal of producing an ecosystem that both looks and functions like a natural ecosystem, a method needs to be devised to assess how well these new ecosystems are meeting the stated goals. To determine the functional success of six created swamps in central and western Kentucky, the hydrology, bird use, insect use, plant establishment, soil structure, and water quality improvement were examined. All the wetlands were compared to the known structure and function of natural bottomland hardwood forests in the region. Most sites did not have a characteristic wetland hydroperiod, and two did not get flooded during a 100 y flood event in March of 1997. The organic matter content of the soils were below the reference standard at four sites, and two sites met or exceeded reference standard concentrations. All but two sites were dominated by herbaceous vegetation. Tree planting was done at all sites, but only two of the sites had trees large enough to be ecologically significant for wildlife dependent upon woody vegetation. Wetland vegetation dominated all sites; however, some still had significant quantities of old-field species. Water quality was improved by only a few constructed/restored wetland sites. All the wetlands were constructed in accordance to the Commonwealth of Kentucky's criteria for wetland restoration; however, they have not had sufficient time to establish the biota and functions characteristic of natural bottomland hardwood forest. Three of the sites studied may, in time, reach the stated goals. At two sites the topography may preclude the establishment of a functional wetland. One site is situated in a very poor-quality landscape position between a landfill and a divided highway.

Accepted by: _______________, Chair

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1.0 Introduction

Since presettlement times, over 50% of the wetlands in the conterminous 48 states have been lost due to agricultural, silvicultural, and urban developmental activities. In this time period, Kentucky lost approximately 80% of its wetlands (Dahl, 1990). In 1987, approximately 55% of all wetland acreage in the conterminous 48 states was forested. In the Appalachian subregion, 77% of all wetland acreage was forested (Cubbage and Flather, 1993). To mitigate for the losses to society when bottomland hardwood forests or swamps are destroyed, state and national laws and policies require new bottomland hardwood forests and swamps to be created or restored when destruction is unavoidable.

Wetland mitigation plans usually emphasize replacing appropriate acreage or "no net loss", rather than requiring restoration of wetland functions and values (Zedler, 1996). Recently, wetland scientists and managers have recognized that focusing only on acreage may not adequately address the losses to society when a wetland is destroyed. Therefore, suggestions have been made to address the loss of functions and values that the wetland provided to society or the region. Functions, such as self maintenance, production, and water retention are attributes that a wetland possesses regardless of whether society uses the wetland or not (Walbridge, 1993). Wetland values are determined by its usability to society, which can be quantified using a variety of methods (Walbridge, 1993). For example, the ability of a wetland to clean water can be compared to the cost of a water treatment plant, or the ability of the swamp to attract and nourish waterfowl can be quantified in dollars spent on hunting or bird-watching. Considerable controversy exists over how to quantify these values; however, Costanza et al. (1989) recently suggested that natural ecological functions contribute substantial economic support to the earth. The economical benefit a wetland can give to a community through flood control, tourism, and wildlife diversity, was recently estimated to be \$200,000 acre^{-1} (Redington, 1994).

Wetland scientists have likewise been asked to quantify the value of wetlands. This is partly in response to decision-makers who desire a "cost benefit analysis" for development projects in order to accurately ascertain the true costs of environmental regulations. Wetland scientists have responded to this call by developing a new assessment model, the Hydrogeomorphic Index (HGM), that takes into account quality as well as quantity (Brinson, 1993). The regional models being developed compare the functions (e.g. water quality enhancement, wildlife diversity, plant habitat, flood control) of the site being studied to reference standards for the same wetland class (Brinson, 1993). Wetland class is determined by dominant biota, hydrology, and geographic region (Brinson, 1993; Brinson and Rheinhardt, 1996). It is expected that the HGM will suggest the mitigation acreage required to compensate for the loss of values and functions provided by the destroyed wetland (Brinson, 1993; Brinson and Rheinhardt, 1996).

The goals of this study were to gather and analyze data about the structure and functionality of six constructed or restored swamps in central and western Kentucky to determine if they function similarly to "natural" wetlands in their region. This determination was accomplished by measuring water quality improvement, species diversity (including plants, insects, and birds), and hydrology. This information was compared to known information about bottomland hardwood forests and swamps to determine if these wetlands provide a value to society comparable to those that were destroyed.

2.0 Literature Review

Wetlands are ecologically rich, playing a variety of roles for animals and humans (Kusler et. al., 1994). Wetlands are delineated as areas with shallow water, hydrophytic vegetation, and hydric soils. Therefore, the objective of any wetland restoration and construction is to re-create those three components (Young, 1996). A dramatic increase in wetland construction took place in the early 1980's. The results were disastrous, because knowledge concerning wetland restoration was limited and engineers with very little wetland experience were trying to build these complex ecosystems (Young, 1996). Analysis of recent restoration projects has found that wetland functions are hard to re-create, and even if present, some do not meet the criteria to be judged a success (Young, 1996). With the rapid loss in natural wetlands, restoration techniques are becoming important in the struggle to prevent the further loss of wetlands in the United States.

Wetland construction and restoration is a young science. Much of the literature concerning constructed and restored wetlands is recent (Mitsch and Gosselink, 1993). For over a century in the United States, wetlands were drained or filled, mostly to facilitate agriculture or development (Ewel and Odum, 1984). Most states require that wetlands constructed for the purpose of replacing lost wetland acreage (mitigations) are built in the same or adjacent watersheds so functions and values are retained for the people most affected by wetland destruction (Mitsch and Gosselink, 1993).

2.1 **Forested Wetland Creation/Restoration**

Forested wetland creation/restoration projects are more difficult than marsh restorations because the former ecosystem may take many decades to reach maturity, rather than only a few years. Consequently, the criteria for success is less clearly defined because the designer must predict what the site will look like in future generations (Kruzynski, 1990; Mitsch and Gosselink, 1993; Zedler, 1996). Most projects that have been completed are young--usually less than 10 years old. Therefore, criteria for success cannot be determined by direct measurements, since long time periods will be needed to ascertain if the restored and created wetlands reached desired goals. Those mitigation sites that are farther along in development have displayed very low rates of success (Eliot, 1985; Mitsch and Gosselink, 1993; Race and Fonseca, 1996; Zedler, 1996; Perry et al.,1997). As noted by Young (1996), constructed wetlands that have been successful are those designed to perform a specific function (e.g. wastewater treatment, wildlife habitat, and erosion prevention). The lack of sufficient data to design forested wetlands compounds the problems being encountered in the mitigation process (Cubbage and Flather, 1993; Mitsch and Gosselink, 1993; Mitsch and Wilson, 1996).

2.1.1 *Hydrology*

Hydrology is accepted as the primary component driving the development and functioning of a wetland ecosystem (Gosselink and Turner, 1978). Wetland ecosystems are often defined by the type of hydrology the area experiences (e.g. seep marshes, deep water swamps, riparian, and tidal). Bottomland hardwood forest hydrology is characterized by intermittent flooding of nearby rivers and streams and/or high groundwater levels (Conner et al., 1990; Bedford, 1996). Bottomland forests are flooded annually, and retain floodwater 6% to 40% of the time (Taylor et al., 1990). Erwin (1991) found that a majority of wetlands deemed "incomplete" or "failures" in south Florida did not restore correct water levels and hydroperiods. The replacement of any wetland will not be successful unless wetland hydrologic features can be restored or duplicated (Bedford, 1996).

Hydroperiods for cypress/hardwood swamps or bottomlands range from 120-150 days (Ewel and Odum, 1984). As seen in Figure 1, the hydroperiod for Waldo cypress stand in Florida had water at or above surface level for more than 250 days during the year long study (Ewel and Odum, 1984).

2.1.2 *Water Quality*

Wetlands are thought to be effective in removing surplus nutrients, sediments, metals and other contaminants from surface water (Taylor et al., 1990). Wetlands retain nutrients and contaminants in the sediment because of the low flow rate through the wetland (Mitsch and Reeder, 1992). These macro- and micronutrients are then

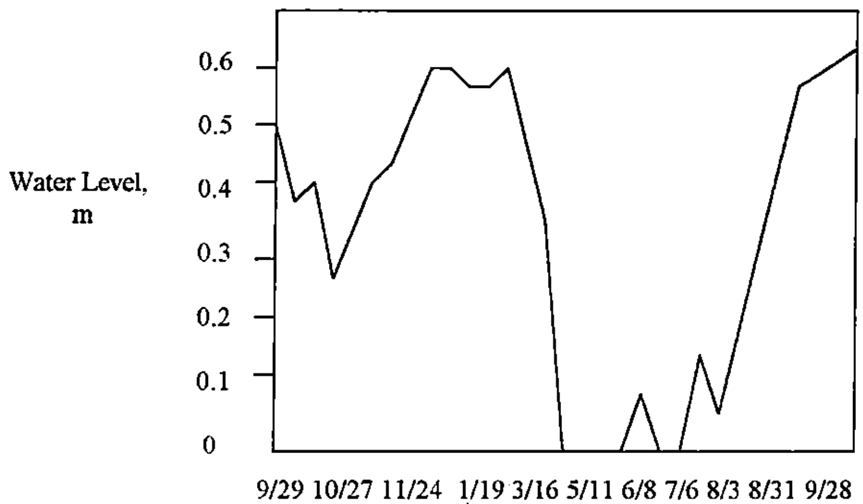


Figure 1. Hydroperiod for Waldo cypress stand in Florida. (Adapted from Ewel and Odum, 1984)

used by the vegetative communities in the wetland. The vegetative uptake of these nutrients from the sediment probably does not affect water quality directly, but may increase the movement of nutrients from the water to the sediment (Taylor et al., 1990). Bottomland hardwood forests accomplish this ecological function in different ways with variable degrees of success. Water quality enhancement relies on vegetative uptake and on the hydrologic features of the watershed. Nutrient retention can be seasonal or temporary depending on where the nutrients are stored (Taylor et al., 1990).

The absorption and chemical conversion of nutrients by wetlands are important processes in water quality enhancement (Taylor et al., 1990). Studies have shown that forested wetlands are very effective in removing or converting nutrients such as nitrogen and phosphorus (Blood, 1980; Kuenzlar et al., 1980). Blood (1980) demonstrated that inorganic nitrogen composed 49% of the input into Okefenokee Swamp, but only composed 2% of the output. Kuenzlar et al. (1980) found that the total phosphorus input to Creeping Swamp, North Carolina was 63%, while the output was 52%. The input and output of nutrients in three other swamps is shown in Table 1.

2.1.3 *Soil Development*

Wetland soils have characteristics that differentiate them from other soils. The color of wetland soil ranges from medium grey to black (Brady, 1990). The water

Table 1. Water quality enhancement for different forested wetlands in the southeast (g/m^2yr^{-1}) (adapted from Taylor et al., 1990).

Site	Nutrients	Input	Output	Net uptake (%)	Source
Cypress Swamp, LA	Total P	.374	.200	.174 (46)	Day et al., 1974
	Total N	2.960	1.360	1.330 (49)	
Cypress-tupelo, enriched, LA	Total P	4.20	2.510	1.690 (40)	Kemp & Day, 1981
	Total N	15.54	11.620	3.920 (25)	
	NH_4	.620	.250	.370 (60)	
Okefenokee Cypress Swamp, GA	Total P	.570	.144	.426 (75)	Blood, 1990
	Total N	1.753	1.070	.683 (39)	
	NH_4	.349	.014	.335 (96)	

retention capacity of wetland soil is approximately 2 to 4 times its own dry weight (Brady, 1990). The average percent organic content for wetland soils should range from 20% to 35% for forested wetlands, but can be much higher (Mitsch and Gosselink, 1993). The soil color, water retention capacity, and average percent organic matter for wetland soils is shown in Table 2.

Soil is important in the hydrology and vegetation of the wetland. A proper hydroperiod will not exist, regardless of the amount of inflow, if hydric soils are not present (Tiner, 1993). The presence of proper soil is also necessary for appropriate plant succession to occur (Gleeson and Tilman, 1990; Bridgham and Richardson, 1993).

2.1.4 *Vegetation*

Plant communities are the third major component in wetland classification. They can be divided into herbaceous (dominant in marshes), woody (defining swamps) and planktonic (open water) communities. Tiner (1991) reviewed data from numerous studies that had been previously conducted to better understand the relationship between hydrologic regimes and the ability of plants to tolerate varying degrees of wetness.

Plants with hydrophytic adaptations are defined as being characteristic of wetlands. The classification system used at present for wetland species was developed by Reed (1988). This system classified plants based on the habitat they are most likely

Table 2. Soil texture, color, drainage and wetness, and organic content for typical bottomland hardwood forests (adapted from Taylor et al., 1990 and Touchet, 1990).

Soil texture	Soil Color	Soil Drainage and wetness	Organic content %
Silty clays or sands	Gray to olive gray with greenish gray, bluish gray, grayish green mottles	Very poorly drained to poorly drained, very wet, hydric soils	>18.0
Dense clays	Gray with olive mottles	Poorly drained to somewhat poorly drained, wet, hydric soils	>5

to be found in. The plants expected to be in wetlands are those classified as facultative, facultative wet, and obligate (Reed, 1988).

There are two basic ways to introduce vegetation in restored and created wetlands: 1) introducing species and then expecting them to survive in Gleasonian zones (i.e. landscape architecture) or 2) utilize the "self-design" capability of nature to recruit adjacent suitable species or to choose from a wide variety of possible species planted or sowed by humans (Odum, 1989; Mitsch, 1993; Mitsch and Wilson, 1996). A study currently being conducted at the Olentangy River Wetland Park in Columbus, Ohio, is attempting to determine whether the "designer" or "self-design" wetlands are capable of functioning as natural wetland ecosystems (Mitsch and Wilson, 1996). Purposeful plantings in created wetlands tend to have low survival rates (Mitsch and Gosselink, 1993; Zedler, 1996; Perry et al.,1997). Perry et al. (1997) found that the majority of woody plant growth in constructed wetlands was from volunteer plants, while planted species had a 35% mortality rate. The mortality rate listed by Perry et al. (1997) is considerably higher than the mortality rate of 10-20% for most hardwoods (Jeff Lewis, USFS, personal communication).

Creation or restoration of bottomland hardwood forests consists mainly of planting woody vegetation. The species of trees to be planted are determined by the hydrology of the area. Bottomland hardwood forests are usually planted with species that are tolerant of seasonal flooding or high groundwater throughout the year (Kusler and Kentula, 1990). A list of eighteen bottomland hardwood species and their growth rates, competition tolerances, and periodic flooding tolerances is shown in Table 3. The species selected for wetland mitigation projects can have growth rates from slow for bald cypress, *Taxodium distichum,* to very rapid growing trees such as eastern cottonwood, *Populus deltoides,* (Conner et al., 1990). The planting of rapid growing trees with slower growing trees may result in the loss of trees that are intolerant of competition, thus increasing mortality rates.

Plant communities also play an important role in creating a proper hydroperiod (Tiner, 1993). Plant cover decreases evaporation from the soil, which increases the amount of moisture available to the plants. The presence of hydrophytic vegetation can be used as an indicator of proper hydrology without observation of inundation or saturation (Tiner, 1993).

2.2 Assessment

Wetland construction requires an interdisciplinary approach during both the design and analysis phases (Young, 1996). Engineers must properly combine the three main components of water, soil, and plants to create the habitat and functions that were destroyed. Numerous methods to assess the ability of a constructed wetland to perform certain functions have been proposed in recent years. The method presently receiving the most attention is the Hydrogeomorphic Index.

2.2.1 *Hydrogeomorphic Index*

The HGM determines the functional capacity of a wetland to be destroyed based on three main components: 1) hydrology; 2) soil; and 3) plant composition. This

Table 3. Bottomland hardwood trees typically planted in creation or restoration projects and their growth rate, competition tolerance, and periodic flooding tolerance (adapted from Conner et al., 1990).

Species	Growth Rate	Competition Tolerance	Periodic Flooding Tolerance
Green Ash	Medium	Intolerant	Tolerant
Eastern Cottonwood	Very rapid	Very intolerant	Tolerant
Bald Cypress	Slow to medium	Moderately tolerant	Very tolerant
Sweetgum	Medium to good	Intolerant	Intermediate
Shumard Oak	Good to excellent	Intolerant	Very intolerant
Swamp Chestnut Oak	Medium to good	Moderately intolerant	Intolerant
American Sycamore	Good to excellent	Very intolerant	Tolerant
Silver Maple	Excellent	Intolerant	Tolerant
Nuttall Oak	Good to excellent	Intolerant	Intermediate
Willow Oak	Good to excellent	Intolerant	Tolerant
Swamp Tupelo	Medium	Moderately intolerant	Very tolerant
Black Willow	Excellent	Very intolerant	Tolerant
River Birch	Good	Intolerant	Intermediate
American Elm	Medium	Tolerant	Intermediate
Hickory spp.	Poor to good	Very tolerant	Intolerant
Red Maple	Medium to good	Tolerant	Tolerant
Overcup Oak	Poor to medium	Moderately tolerant	Tolerant
Pin Oak	Good to excellent	Intolerant	Intermediate

information is then used to determine the appropriate type and size of wetland that should be constructed to best replace the one being destroyed (Brinson, 1993). The HGM is useful because it is a quick tool for assessing wetlands. It can be used in any season and allows the assessor to look for basic functions that are present in a wetland. The HGM is also used to determine the success of the constructed wetland as compared to the wetland that was destroyed or degraded based on the similarities in function.

Brinson and Rheinhardt (1996) suggested that HGM regional models may have a number of shortcomings. The HGM procedure can be used in any season; however, this can cause misinterpretation of data obtained during a particular season. Those involved in wetland mitigation projects want a quick and decisive assessment tool that can be used any time during the growing season. This seems reasonable given the considerable costs that could be incurred if a construction project is delayed. However, from an ecological standpoint this is unacceptable. Adequate databases do not exist to allow telematologists to assess complex functions (hydrology, biodiversity, and productivity) with any degree of certainty based on a single visit to the site. For example, spring flooding could cause flood control capacity overestimates, and fall assessments of plants may miss wetland species that were present in the spring.

The HGM model is completely dependent upon the reference standard used to gauge the proposed site (Brinson and Rheinhardt, 1996). The reference wetlands selected will be used not only for the design criteria for mitigation projects, but also will be the measuring tool used to evaluate the mitigation sites. Therefore, the reference wetland selected should: 1) not be a degraded ecosystem; 2) not have unusually high standards so as to make attainability impossible; and 3) the position of the reference wetland in the landscape should be similar to those it is compared to (Brinson and Rheinhardt, 1996). For example, if the reference site is near a suburb, species of birds and plants may be found that are not characteristic of a wetland.

3.0 Methods

3.1 Site Descriptions

Six constructed or created wetlands, selected by the Kentucky Division of Water, ranging in size from 4.5 ha. (11 ac.) to 117 ha. (290 ac.), were studied March 17-20, May 27-30, July 14-17 and September 10-12, 1997 in central and western Kentucky. Each site was visited four times, except Henderson, which was not studied in March due to flooding. All sites were constructed to mitigate for the unavoidable loss of wetlands due to construction projects. The classification (Cowardin et al., 1979), landscape position (Brinson, 1993), and size for each constructed wetland are provided in Table 4. Depressional sites refer to ponded sites that were dredged out. Riverine sites are those constructed in floodplains.

3.1.1 *Henderson Wetland*

The Henderson restored wetland is located in Union County, Kentucky, on County Road 1574 adjacent to the Ohio River. This wetland is approximately 28 ha. (70 ac.) in size and is surrounded by farmland.

3.1.2 *Carrollton Wetland*

The Carrollton constructed wetland is located in Owen County, Kentucky, on State Route 355, approximately one mile east of the Kentucky River. The wetland is approximately 4.5 ha. (11 ac.) and is bordered on three sides by pasture and on the other side by upland hardwood forest.

Table 4. Site, classification (Cowardin et al., 1973), landscape position (Brinson, 1993), soil type, and area for six constructed wetlands in central and western Kentucky (PEM-palustrine emergent, PFO-palustrine forested, PSS-palustrine scrub-shrub, POW-palustrine open water).

Site	Wetland Class Original	Landscape Position	Wetland Class Present	Soil Type(s)	Area
Henderson	PEM	Riverine	PFO/PSS	Huntington Silt Loam, Newark Silt Clay	28 ha (70 ac)
Carrollton	PSS	Slope/Fringe	PEM/POW	Zipp Silty Clay Loam	4.5 ha (11.3 ac)
Outer Loop	PSS	Depressional	POW	Zipp Silty Clay	58 ha (144 ac)
Bardstown	PSS	Riverine/Slope	PEM/PFO	Various Silt Loams	117 ha (290 ac)
Mill Creek	PFO/PEM	Riverine	PFO/PEM	Melvin Silt Loam	83 ha (205 ac)
Andalex	PSS	Riverine/Depressional	PEM	Various Silty Loams, Silty Clay	71 ha (175.2 ac)

3.1.3 *Outer Loop and Bardstown Wetlands*

The Outer Loop constructed wetland along with the Bardstown restored wetland are part of a mitigation effort conducted by Waste Management of Kentucky Inc.. The Outer Loop restoration project is on-site mitigation in Jefferson County and was designed to restore 58 ha. (144 ac.) of wetlands. The Bardstown restoration wetland is off-site mitigation in Nelson County and was designed to restore 117 ha. (290 ac.) of bottomland hardwood forest.

3.1.4 *Mill Creek Wetland*

The Mill Creek mitigation area comprises approximately 83 ha. (205 ac.) located in Jefferson County, and it lies in a corridor ranging from 181m to 454m (600ft to 1500ft) in width. The wetland is bordered on the north by Greenwood Road, on the south by Johnstown Road, and State Route 1934 to the west.

3.1.5 *Andalex Wetland*

The Andalex mitigation area is located near Madisonville in Hopkins County, Kentucky, in the Pond River floodplain. The mitigation area consists of two separate areas, area A comprising 36 ha.(89.2 ac.) and area B comprising 35 ha.(86 ac.), adjacent to existing wetlands and mitigation projects conducted by Andalex.

3.2 **Field Assessment**

3.2.1 *Water Quality Measurements*

A Hydrolab® was used to determine water temperature, dissolved oxygen, pH and conductivity at both the definable inflow and outflow of each wetland. The

Hydrolab® was calibrated for pH with a 1 point buffer at a pH of 7.00; dissolved oxygen was air calibrated, temperature and conductivity were calibrated using NIST standards. Water samples were collected, once each visit, at definable inflows and outflows at a sufficient depth to ensure filling of the acid washed 500mL Nalgene bottles. The samples were promptly put on ice to ensure minimal change in water chemistry until chemical analysis could be conducted. Immediately after retrieval sub-samples were filtered and analyzed for NO_3^-, Fe^{++}, NH_4^+, and soluble reactive phosphorus (SRP) concentrations. The spectrophotometer was calibrated by using at least 4 standards within the ranges of concentrations measured. Nitrate, iron, and SRP concentrations were all determined by the Hach Accuvac® method. Ammonium concentration was determined using Nessler's method and by using Hach Salisicate Test'n'Tube® method (Hach Chemical Co., 1996).

3.2.2 *Hydrology*

Hydrologic budgets for each site were calculated based on historic precipitation data, evapotranspiration data, river flow data, wetland area, and wetland watershed area (Table 5). The annual precipitation data were compiled from the World Climate Data and National Climate Data Center. The evapotranspiration data were gathered from the Midwest Climate Center in Champaign, Illinois. River flow data were obtained from the United States Geological Survey for the Uniontown Dam at Uniontown, Kentucky, USA. The wetland and watershed area was calculated using topographical maps and a polar planimeter.

Table 5. Hydrologic budgets for constructed wetlands in central and western Kentucky.

Site	Annual Precipitation m^3y^{-1}	River Addition m^3y^{-1}	Evapotranspiration m^3y^{-1}	Total m^3y^{-1}
Henderson	871,943.7	1.066 X 10^{17}	826,051.96	1.0667 X 10^{17}
Carrollton	186,032.5	N/A	196,765.14	-10,732.74
Outer Loop	2,168,269.2	N/A	2,168,269.2	0
Bardstown	2,932,692.4	Unknown	2,644,203.8	288,461.58
Mill Creek	5,309,615.4	Unknown	5,309,615.4	0
Andalex	4,599.707	Unknown	4,174,615.4	425,091.6

3.2.3 *Soils*

Soil samples were collected at random from each site using a bulb planter. The number of samples taken at each site was based on the size of the wetland. The soils were placed in ziplock bags for storage until samples could be analyzed. Soils were sent to the University of Kentucky Soil Lab for mineral analysis. Soil organic content was determined using the loss on ignition method (Dean, 1974).

Soil heavy metal was analyzed using the method similar to that outlined by Burnas (1967). Fifty mg of soil were placed in a Teflon bomb with 2.8 gm of boric acid, 5 ml of Aqua Regia (3:1 hydrochloric acid to nitric acid), and 3 ml of hydrofluoric acid and placed in an 110° C oven for at least one hour. The bombs are taken out and allowed to cool. The volume was then brought to 40 ml in the bomb, and then to 100 ml in a volumetric flask. Five standards were made for each metal tested, by adding 2.8 gm of boric acid, 5 ml of Aqua Regia, and 3 ml of hydrofluoric acid to the standard and taking the volume to 100 ml in a volumetric flask. Metal content of the soils was determined by atomic absorption spectrophotometry.

3.2.4 *Biotic Structure and Function*

3.2.4.1 Aquatic Insects

The three main biotic components studied in each wetland were insects, birds, and vegetation (herbaceous and woody). Originally, aquatic insects were to be collected, and to accomplish this a new sampler was constructed (Figure 2). The sampler was made out of 3in. PVC pipe that was 1.5 m in length. Handles were

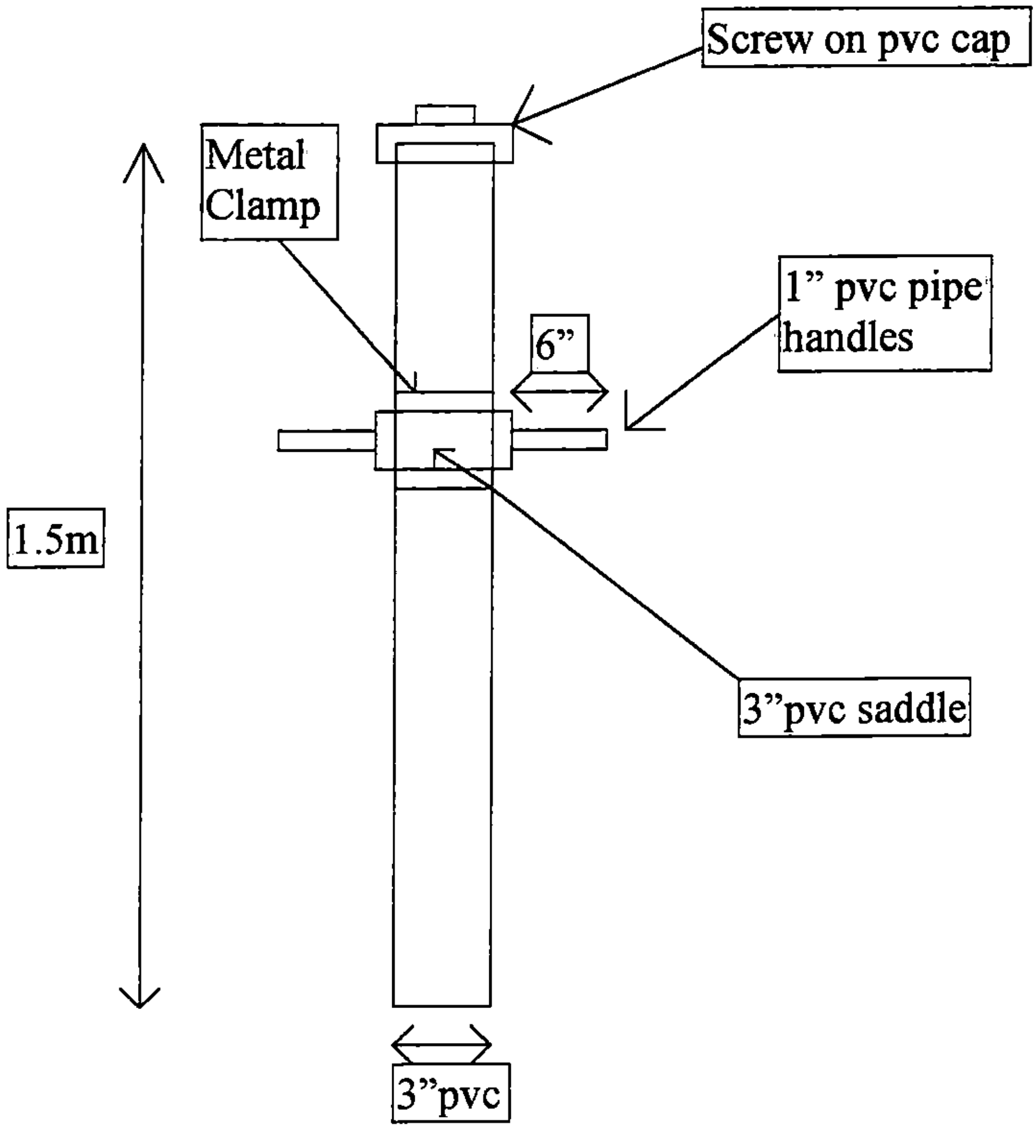


Figure 2. Sampler for benthic macroinvertebrates in wetlands.

created using 2 PVC saddles with a 1' adapter, glued across from each other approximately 1 m from one end. Two 6" sections of 1' PVC pipe were cut and glued into the adapters of the saddles. The saddles were then secured by metal clamps that went around the entire sampler. At the top of the sampler was placed an adapter with a screw on end to help create a suction during sampling. The bottom edge of the sampler was filed down on the sides to create an angle for easier penetration into the substrate. The sampler was then delineated into 10cm intervals so water depth could be easily approximated.

The sampler was very light weight and was fairly easily transported in the field. It was capable of collecting several centimeters of soil and water, which were held sufficiently by the suction created. The handles were under extreme pressure when samples were being collected but did not break. Despite these good qualities, it became evident upon taking the sampler out the first time that it would not work in the wetlands that were being studied. The constructed and restored wetlands had little if any aquatic habitat and few aquatic insect larvae; therefore, the sampler was useless in these wetlands. The sampler should work well when used for aquatic sampling in natural swamps.

3.2.4.2 Adult Insects

Hardin (1992) successfully used insects to categorize nearby Ohio River Basin swamps. Because the wetlands studied herein were lacking similar aquatic areas the emphasis switched to collecting terrestrial insects. This was accomplished by sweep netting a 1 m^2 plot. The number of collection plots in each wetland was determined by the size and diversity of habitats in each. Collections in larger wetlands, greater than 50 ha., were two per 10 ha.; in smaller wetlands, less than 50 ha., collections were five per 10 ha. Each plot was swept three times in opposite directions. This procedure was duplicated to ensure an adequate number of insects were collected. The insects were placed in large plastic jars containing alcohol to preserve them until they could be identified (Merritt and Cummins, 1984).

3.2.4.3 Aviofauna

Birds were the second biotic component studied in the wetlands. The number and diversity of birds were determined by walking several transects that covered the entire wetland. As the transects were walked, birds were identified, if possible, and total numbers were counted for each species. This allowed for multiple counts of a single bird, but was the most effective method for determining the bird communities based on the large size of the wetlands.

3.2.4.4 Vascular Plants

Vegetation of the wetland was the other component studied. Both woody and herbaceous vegetation were quantified in each wetland. The primary method for determining the numbers and importance of woody vegetation was the point quarter method (Brower et al., 1990). Trees for this study measuring under 3m in height and 3cm diameter were not included because of the minimal ecological functions added to the wetlands.

For herbaceous vegetation, 100 m transects were run and a 1 m^2 plot was placed at 25 m and at 75 m. All vegetation in the plot was counted and identified if possible in the field. If field identification was not possible, a specimen was collected and pressed for later identification. The number of transects and plots in each wetland was based on the size of the wetland.

3.3 **Data Analysis**

The data gathered were compared to reference standard data to determine the success of the constructed wetlands. Because the data either did or did not meet the reference standards, the use of statistics was limited. All statistical analysis were performed with Microsoft Excel.

The Shannon Diversity Index was used for insects and birds. All indices were calculated using base 10. Due to the lack of information for reference wetlands concerning insects and birds, they were not compared to any standard. Instead they were compared to known habitat preferences (Kentucky Breeding Bird Atlas and Peterson Field Guide, 1980 for birds; Merritt and Cummins, 1984 for insects). The herbaceous and woody vegetation was evaluated based on wetland classification, which was compared to reference wetlands, to determine mitigation success.

The soil organic content and mineral components were compared to reference standards to determine the success of the mitigation sites in creating hydric soils. The soil heavy metal data were compared to legal limits of the metals in soils to determine if the soils were toxic to the plants in the mitigation area.

4.0 Results

4.1 Henderson Restored Wetland

The Henderson restored wetland is located in Union County on county road 1574 adjacent to the Ohio River. The wetland was created as mitigation for road construction activities by the state of Kentucky.

4.1.1 *Proposed Mitigations*

The mitigation procedures for this site were designed "to restore the farmed wetland areas to natural wetland with minimal construction activities and principally by planting hydrophytic vegetation of bottomland hardwoods and shrubs"(Final Mitigation Plan for Lambert tract, Transportation Cabinet, August 4th 1992).

4.1.1.1 Hydrology

The hydrology for the Henderson restored wetland was to be controlled primarily by the flooding events of the Ohio River, with secondary inflow from precipitation. No alterations to the soil were planned during the mitigation process to enhance the hydrology.

4.1.1.2 Plantings

Planned mitigation for the site included four vegetative zones based on elevation contours.

•Zone A, below 345'msl, was planted in bald cypress *(Taxodium distichum)* using balled and burlap stock only.

•Zone B, between 345'msl and 348'msl, was planted with swamp white oak *(Quercus bicolor)*, willow oak *(Quercus phellos)*, pin oak *(Quercus palustris)*, and swamp dogwood *(Cornus stolonifera)*.

•Zone C, between 348'msl and 350'msl, was planted with pecan *(Carya illinoensis)*, southern red oak *(Quercus falcata)*, cherrybark oak *(Quercus pagoda)*, swamp chestnut oak *(Quercus michauxii)*, winterberry *(Celtis laevigata)*, and hazelnut *(Corylus americana)*.

•Zone E, above 350'msl, was planted with a herbaceous seed mixture.

All species planted were obtained from available nursery stock and supply companies.

4.1.2 *Assessment of Mitigation*

4.1.2.1 Hydrology

This was the only site with surface moisture over a significant area in September, due to the inflows from the Ohio River to the wetland. Because the majority of the wetland is at an elevation below that of the Ohio River at normal pool, the soils do stay wet throughout the year. The wetland receives the majority of inflow from the Ohio River during flood events, with only a minority from precipitation (Table 5); however, during the summer the wetland does not have any areas of standing water. During March, water depth in the wetland exceeded 10 m. This hydrology is considered to be commensurate with that found in natural riverine wetlands.

4.1.2.2 Soils

Soils at the Henderson wetland had organic contents close to reference standard as seen in Figure 3. Organic content of the soil averaged 8.54%. The organic content of the soil for the Henderson site will probably continue to increase because of the extraordinary vegetative growth at the site.

4.1.2.3 Plant Diversity

The woody vegetation growth at this site is phenomenal, with counts of 30-40 saplings m^{-2}. The primary species are *Populus deltoides* and *Salix nigra*, with most of the saplings 4-5 m tall and 3-6 cm in diameter. The importance values (IV) for these two species of 37 and 12.4 respectively, display their density. The other main species of tree identified was *Taxodium distichum*, with most representatives 2-3m tall and 3-5 cm in diameter; however, the IV was 5.4, which is considerably lower than the two dominant tree species. The other planted tree species were not observed in the wetland, this is probably due to the extreme growth of the above three species and the subsequent reduction of available sunlight.

The herbaceous plant IV's indicate that ragweed (*Ambrosia* sp.) and mustards (*Cruciferae*) are the most abundant species with IV's of 13 and 12 respectively. Greater than 50% of herbaceous species at the Henderson site are classified as Facultative Wet to Obligate (Figure 4). This placed it fourth overall among the six constructed wetlands studied.

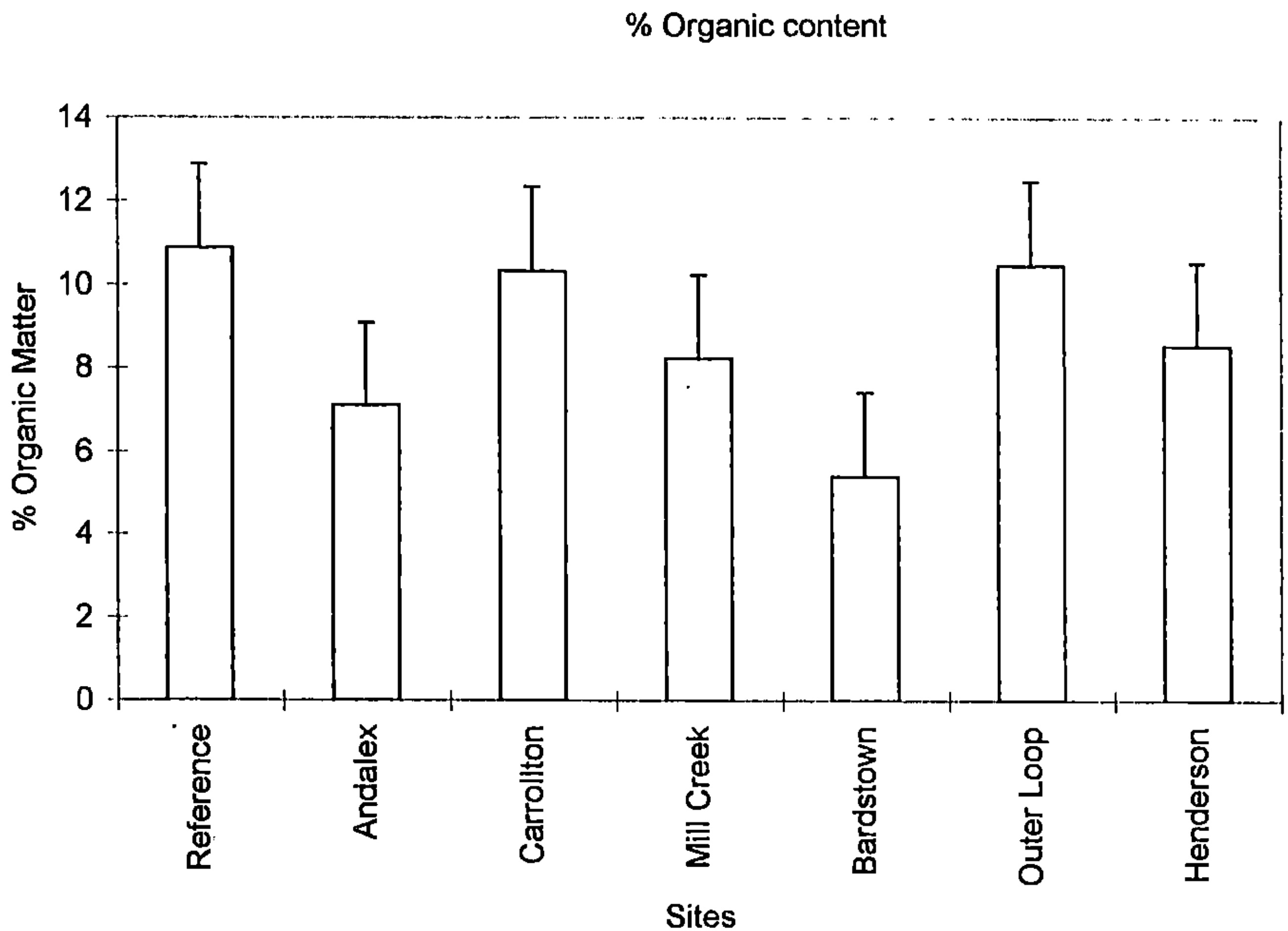


Figure 3. Average organic content for reference wetland and six constructed wetlands in central and western Kentucky.

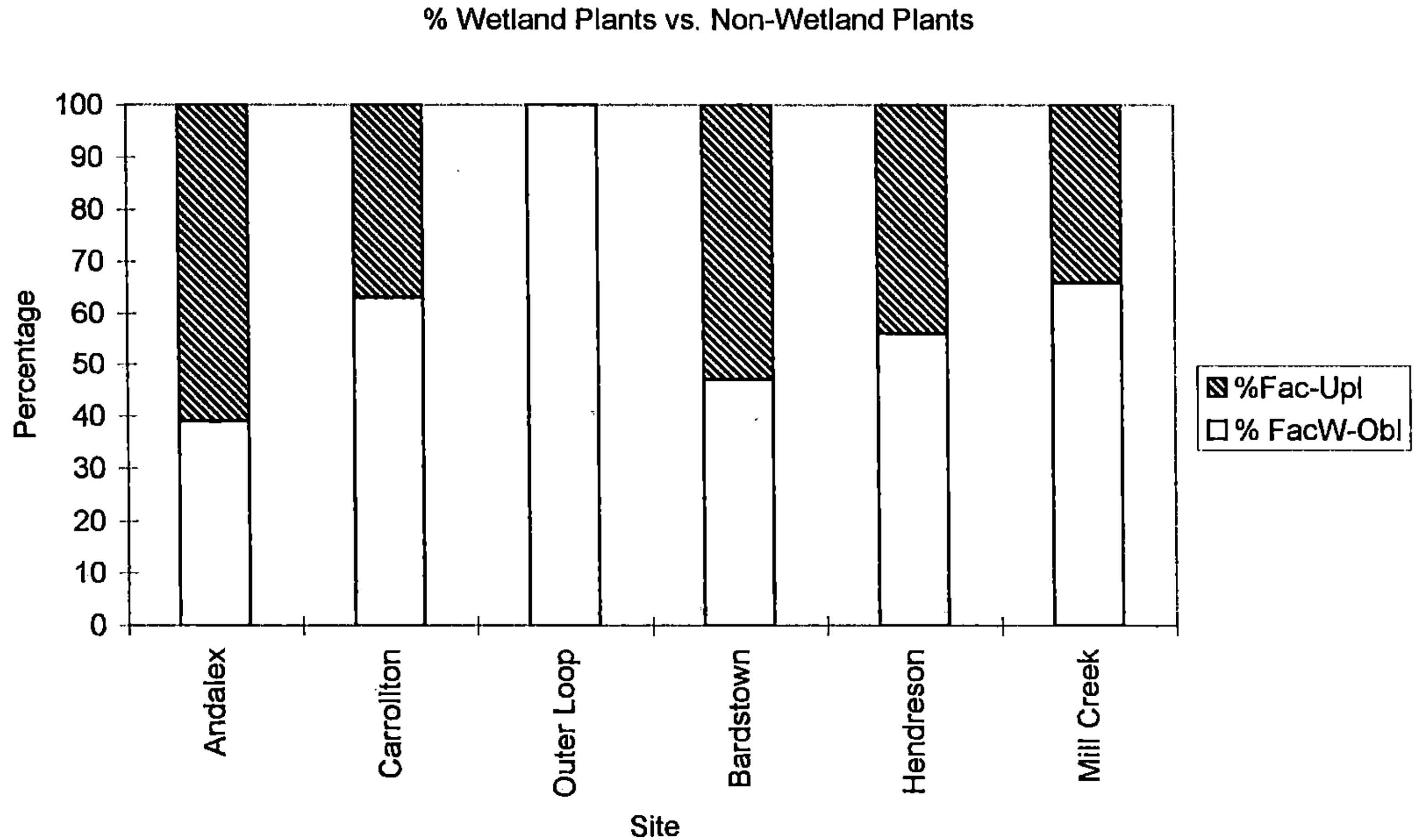


Figure 4. Wetland classification of herbaceous vegetation for six constructed wetlands in central and western Kentucky.

The results obtained for the vegetation at the Henderson site are consistent with the proposed mitigations. Despite the absence of many tree species that were planted, the vegetative zones can be clearly defined in the restored wetland. The woody species present are those found in natural wetlands; however, the herbaceous vegetation is inconsistent with that of a natural wetland.

4.1.2.4 Insect Diversity

The Henderson wetland had 132 insects comprising 16 genera. The Shannon Diversity Index for insects was .81 for the Henderson site which ranked fifth among the wetlands studied (Figure 5).

The habitat classification of the insects found at the Henderson site is shown in Figure 6. The Henderson wetland had the lowest percentage of genera found in wet habitats (6%), with no insects collected being classified as wooded area species.

4.1.2.5 Bird Diversity

Eighty-nine birds were identified at the Henderson site, representing 5 species (Table 6). The Shannon Diversity Index for birds at the Henderson site was .14, lowest of all sites (Figure 7); however, the low diversity index is probably due to dense growth of trees, mentioned earlier, which hindered one's ability to observe and identify birds. Despite the low diversity, 93% of the total observed aviofauna are typically found in wet areas, which represented the highest percent of wetland birds identified for all sites (Figure 8).

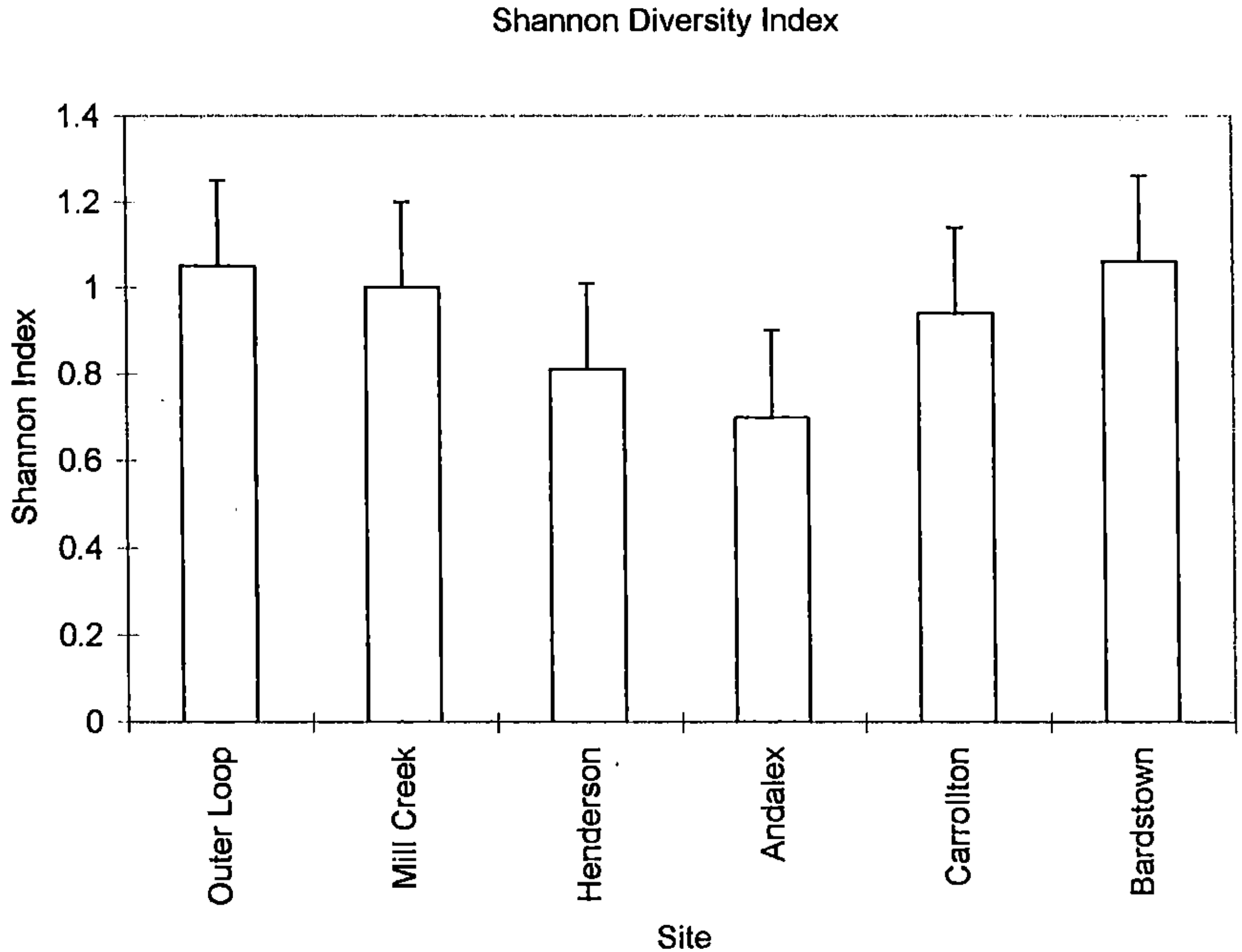


Figure 5. Shannon Diversity Index for insects of six constructed wetlands in central and western Kentucky.

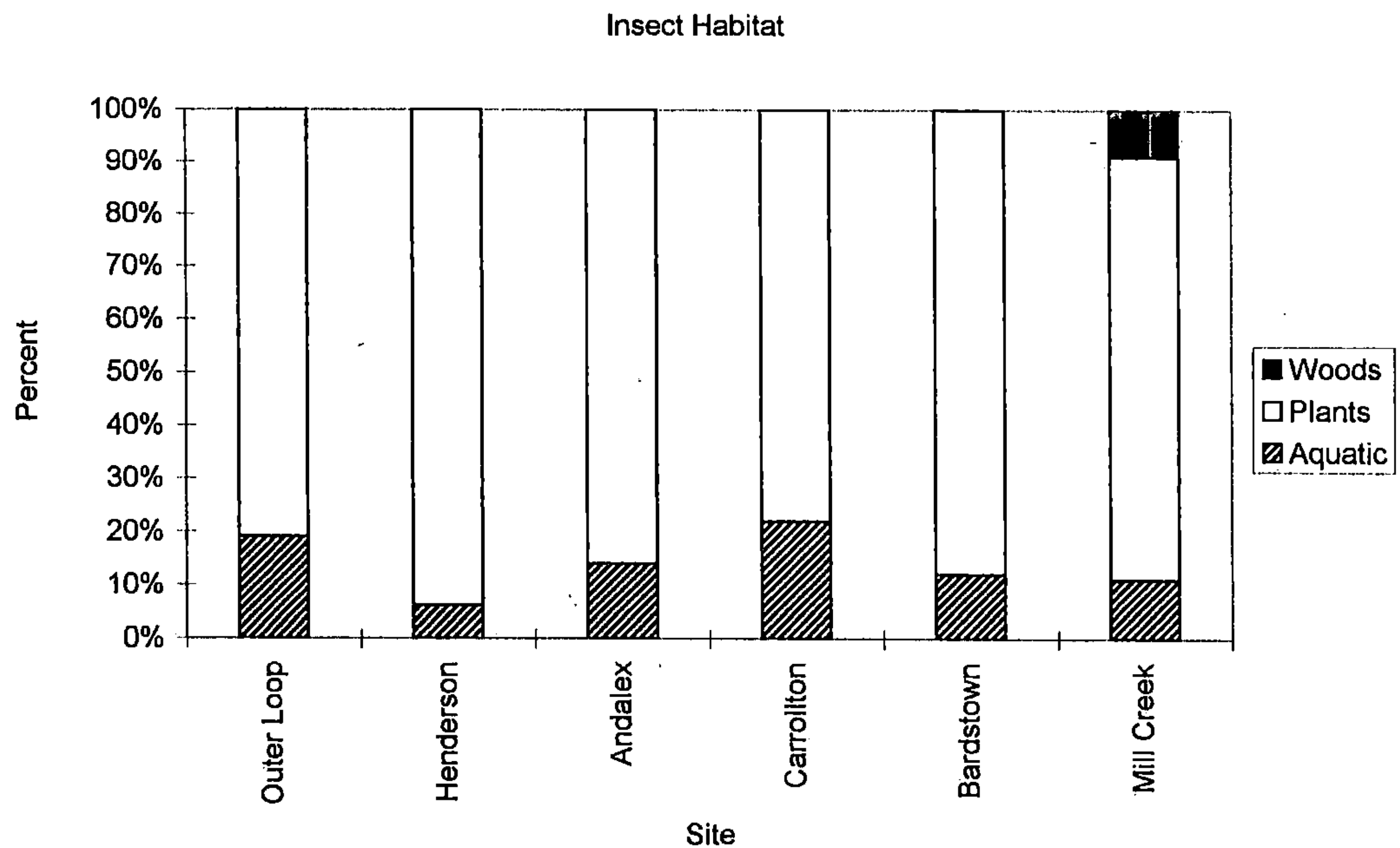


Figure 6. Insect habitat classification for six constructed wetlands in central and western Kentucky.

Table 6. Bird species identified at six constructed wetland in central and western Kentucky. Names follow Peterson(1980).

Species	Andalex	Carrollton	Mill Creek	Outer Loop	Bardstown	Henderson
Black Crowned Night Heron			X			
Cardinal			X		X	X
Dickcissel						X
Eastern Bluebird					X	
Eastern Kingbird		X	X		X	
Field Sparrow	X				X	
Flycatchers			X			
Goldfinch				X		
Grackles			X			
Green Back Heron			X			
Indigo Bunting			X		X	X
Killdeer	X		X	X	X	
King Rail					X	
Kingfisher			X			
Mallard		X	X	X		
Meadowlark					X	
Mourning Dove			X			
Pheobe			X			
Purple Martin		X		X		
Red-tailed Hawk		X	X		X	
Redwing Blackbird	X	X		X	X	X
American Robin					X	
Rufous-sided Towhee			X		X	
Short-eared Owl					X	
Short-tailed Swallow						X
Shoveller				X		
Song Sparrow				X	X	
Starlings			X			
Swift					X	
Tree Swallow				X	X	
Turkey Vulture	X					
Wood Duck		X	X			
Common Yellow Throat					X	

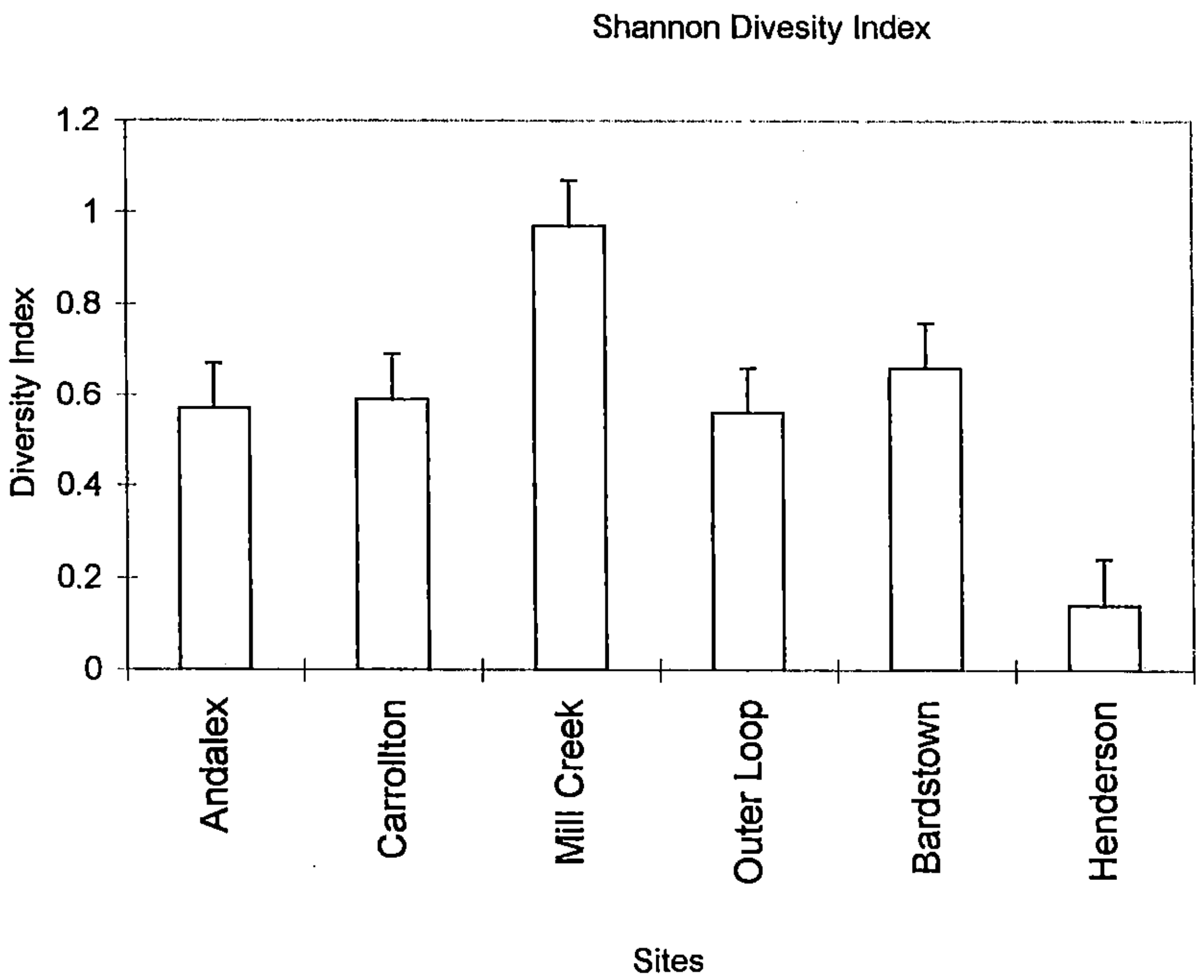


Figure 7. Shannon Diversity Index for birds in six constructed wetlands in central and western Kentucky

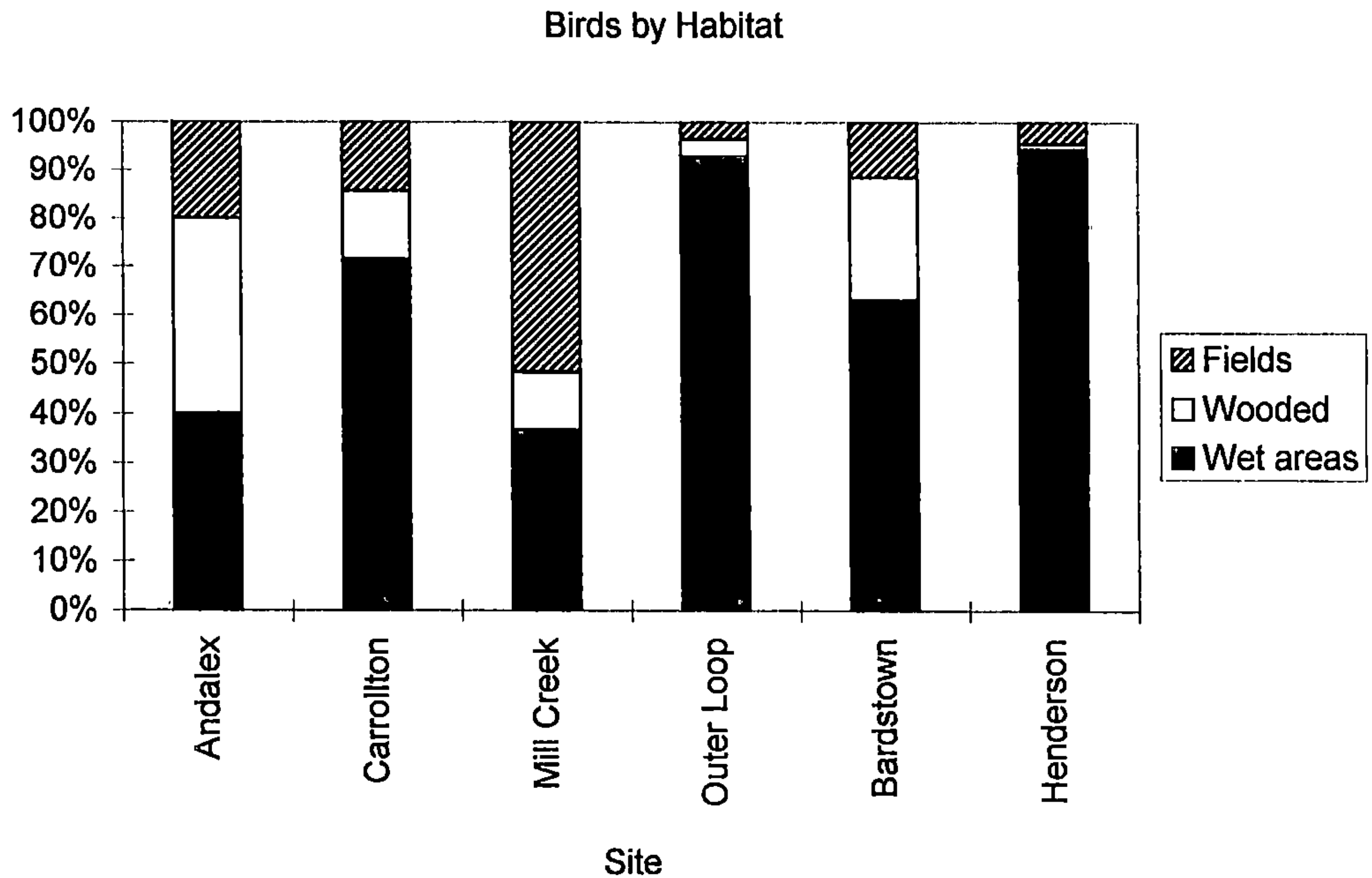


Figure 8. Habitat classification of birds for six constructed wetlands in central and western Kentucky.

4.1.3 *Overall Review*

The Henderson restored wetland, based on hydrology, geology, and to some extent morphology, is considered a wetland; the restored wetland has sufficient hydrology to be classified as a wetland. The site has soil organic content similar to that of the reference wetlands, and the organic content is likely to increase in the future. The site has woody vegetation typical of reference wetlands, but does not have a sufficient amount of Facultative Wet or Obligate herbaceous species found in natural wetlands.

It is very likely that this site, based on the results of this study, will become a bottomland hardwood forest in the future. The Henderson site location is excellent for a mature bottomland hardwood forest to develop from the restored area. Much of the area nearby is dominated by many naturally occurring cypress swamps, which suggests that the mitigation site is well suited for this type of habitat, and will probably allow for plant colonization. The site, as with all sites, is lacking age class diversity.

4.2 Carrollton Constructed Wetland

The Carrollton created wetland is located in Owen County northeast of State Route 355, approximately one mile east of the Kentucky River. The wetland was created due to the loss of wetland area being used as a refuse site for by-products of power plant coal scrubbers.

4.2.1 *Proposed Mitigation*

The mitigation procedures designed for this wetland were to remove ditches that currently drain a row cropped field, thereby establishing wetland hydrology along with the creation of a pond by building a dike (Mitigation plan for Carrollton restored wetland).

4.2.1.1 Hydrology

The primary hydrology of the constructed wetland was provided by sheetflow from an upland forest adjacent to the wetland. The wetland's secondary inflow comes from direct precipitation onto the wetland.

4.2.1.2 Plantings

Vegetation restoration on site included woody species and a mixture of various sedges. Woody species planted on site, included 40% oaks (*Quercus* spp.), 20% sycamore (*Platanus occidentalis*), cottonwood (*Populus deltoides*), and 10% sweetgum (*Liquiambar styraciflua*), and hackberry (*Celtis occidentalis*). Cottonwoods were planted along the south and west border to provide a fast growing buffer strip and scattered through the stand to provide a nurse crop and quick shade. Trees were planted at a frequency of 400/acre on a 12' by 12' spacing. Plants that normally spread by tubers or rhizomes (e.g. *Sagittaria* sp., and *Alisma* sp.) were transplanted to establish populations. The Carrollton wetland area was lacking naturally occurring aquatic flora; therefore, a satisfactory seedbank was not obtained from the site. To resolve this problem, emergent and marginal species were introduced in the wetland by direct seeding and transplanting.

4.2.1.3 Goals

Water quality enhancement goals included reduction of soil and nutrient loading in the Kentucky River, and the treating of runoff both as it passes over the wetland and as it is detained in the impoundment.

Flood flow alteration goals included increased filtration in the vegetated buffer strip around the impoundment and the impoundment was to have a short term pool capacity, above normal, of 2 acre-feet. Aquatic life (macroinvertebrates, algae and aquatic macrophytes) should colonize the 3-acre impoundment.

Goals included creation of permanent habitat for resident species and temporary habitat for migratory birds to increase wildlife diversity.

4.2.2 *Assessment of Mitigation*

4.2.2.1 Hydrology

The results obtained for the hydrology do not meet the proposed mitigations. The Carrollton site had a non-functional hydrologic budget, based on rough estimates, with outflows exceeding inflows by over 10,000m^3y^{-1} (Table 5). Along with the negative hydrologic unputs this site had channelization that is redirecting the water and preventing sheetflow over the wetland. A possible reason for the hydrologic problems at the Carrollton site is the extreme slope from inflow to outflow, which results in rapid runoff from the wetland. There is an area around the impoundment that remains moist at or just below the surface much of the year.

4.2.2.2. Water Quality Enhancement

Water quality enhancement was examined at the Carrollton site (Figure 9a-d). The wetland reduced most nutrients successfully as the water flowed through the wetland, with the exception of Fe^{++} which increased 22.62%. A possible reason for this is the scarcity of oxygen in the water; this condition does not allow for the oxidation and precipitation of Fe^{++} out of the water column.

4.2.2.3 Soils

The average soil organic content for the Carrollton site was above 10%, which is near reference standards (Figure 3). The site had the second highest organic content of all wetlands studied. The organic content in the soil at this site may not increase over time due to the oxidized state of the soils.

4.2.2.4 Plant Diversity

In the Carrollton wetland, 63% of all herbaceous species identified were Facultative Wet to Obligate -- with *Carex frankii* having the highest IV of 40. Thirty-seven percent of the species identified were Facultative to Upland, (Figure 4) with Johnson grass (*Sorghum halepense*) having the highest IV of 27. To this point the herbaceous vegetation surrounding the pond is similar to that found in natural wetlands, but many improvement could be made to the rest of the site. The Carrollton

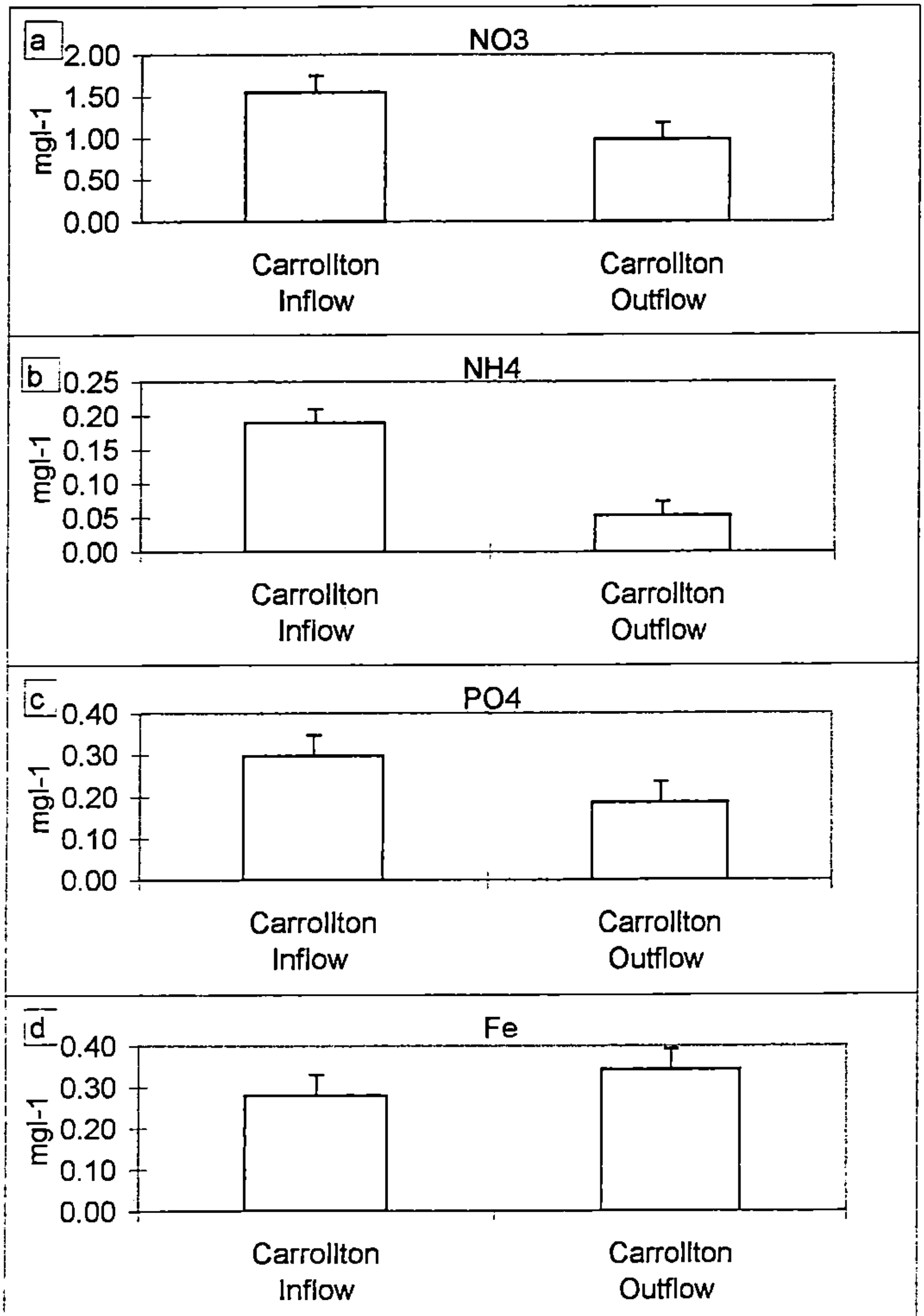


Figure 9a-d. Water quality enhancement for Carrollton constructed wetland.

site did not have any woody vegetation that met the minimum measurements to be considered in this study.

4.2.2.5 Insect Diversity

Seventy-nine insects representing 27 genera, which was the second highest number of genera in all wetlands studied, were found at the Carrollton site. The Shannon Diversity Index for insects at the Carrollton wetland was 0.94--which was fourth among the wetlands studied (Figure 5).

The habitat classification of the insects found at the Carrollton site is shown in Figure 6. The Carrollton wetland had the highest percentage of genera found in wet habitats (22%), with no insects collected being classified as wooded area species.

4.2.2.6 Bird Diversity

The Carrollton wetland had 21 birds identified belonging to 6 different species (Table 6). The Shannon Diversity Index for birds at the Carrollton site was 0.59--which was third among wetlands studied (Figure 7). When the birds were separated based on habitat usage, 71% of all birds identified were classified as using wet habitats (Figure 8). The majority of the 71% came from Redwing Blackbird sightings.

The results of the bird transects suggest that the wetland is being used by both permanent populations and migratory populations. This is consistent with the goal of creating a wetland for the dual purpose of local and migratory populations.

4.2.3 *Overall Review*

The Carrollton site has areas that could be considered jurisdictional wetland, but a majority of the site could not be classified as a wetland. Portions of the site around the pond have standing water and the majority of all wetland plants identified came from these areas immediately surrounding the pond. The portion of the site above the access road is several meters in elevation above the pond and on a slope that will likely never become wetland. There are channelization problems evident throughout the site, which are a result of the landscape position of the wetland. This site is providing some water quality enhancement and habitat refuge, but is deficient in other areas. It is unlikely, based on the present state of the site, that the entire site will become a bottomland hardwood forest, and only the area around the pond, approximately one third of the site, should be considered a wetland.

4.3 **Outer Loop Constructed Wetland**

The Outer Loop wetland, located in Jefferson County, Kentucky, is bordered on the north by an existing landfill, I-65 on the east, Outer Loop Road on the south, and the Slop Ditch on the west. The project is the on-site part of a larger mitigation project to mitigate for the loss of a bottomland hardwood area due to the expansion of the landfill.

4.3.1 *Proposed mitigations*

The stated proposed mitigation plan was "designed to restore/enhance wetland hydrology and bottomland hardwood forest habitat in the designated on and off-site mitigation areas" (Outer Loop restored wetland proposal).

4.3.1.1 Hydrology

Hydrologic restoration at the on-site location was accomplished by rerouting high water flows from the Slop Ditch and the lowering of the existing grade. Slop Ditch flow was intercepted by a defined channel which bypassed the mature bottomland hardwood forest along the site's eastern border, after which it spreads into sheetflow over a broad floodplain. Creation of the floodplain was accomplished by excavating approximately 2.5-4 m below the existing grade. This gave a gradual decrease in elevation of the floodplain from 447' msl on the eastern border where the Slop Ditch intercepted flow empties into the floodplain, to approximately 445' msl where the floodplain empties back into the Slop Ditch on the western border of the site. The floodplain narrows to 160' so water can flow under the access road as it flows to the western border of the site.

4.3.1.2 Plantings

Vegetation restoration in the Outer Loop mitigation area was begun once hydrologic restoration was completed. The objective was to restore bottomland hardwood species in the mitigation areas using standard silviculture practices, including mechanical site preparation and the planting of bottomland hardwood tree seedlings, saplings, and acorns. Topsoil from the site was stockpiled and used for surface soil amendment prior to planting. Species selected were bottomland hardwoods native to the region. Two zones were developed and species were selected for these zones based on their tolerance of inundation and saturation.

•Zone A consisted of species with higher tolerances to inundation, such as pin oak *(Quercus palustris)*, swamp chestnut oak *(Quercus michauxii)*, black gum *(Nyssa sylvatica)*, bitter pecan *(Carya aquatica)*, green ash *(Fraxinus pennsylvanica)*, and river birch *(Betula nigra)*.

•Zone B consisted of species that can tolerate extended periods of dry conditions, such as red maple *(Acer rubrum)*, shumard oak *(Quercus shumardii)*, bur oak *(Quercus macrocarpa)*, cottonwood *(Populus deltoides)*, persimmon *(Diospyros virginiana)*, and sweetgum *(Liquidambar styraciflua)*.

Two to three foot samplings were planted at a frequency of 430/ac which resulted in trees being planted on 10' centers, with the goal of 80% survival.

4.3.1.3 Goals

Specific goals were not established other than those stated in the proposed mitigation statement. The goals outlined were to restore and enhance a bottomland hardwood forest and wetland hydrology.

4.3.2 *Assessment of Mitigation*

4.3.2.1 Hydrology

The wetland's primary inflow was overflow from the Slop Ditch, which results in sheetflow over the wetland from east to west, with secondary inflow coming from precipitation. The wetland was inundated during the visits in March, June, and July, with a large open water area in the southwestern section; however, the wetland was dry in October. The flow of the wetland at this site reversed directions, from east to west in March, to the opposite in June. The cause of this reversal was the pumping of the wetland to allow for construction that was taking place during the visit in October. The area has a sufficient hydrologic budget to be considered a wetland with inflows exceeding outflows by over 200,000 m^3y^{-1} (Table 5). The hydrology of the area meets the goal of the proposed mitigation to restore wetland hydrology to the area.

4.3.2.2 Water Quality Enhancement

Water quality enhancement was examined at this site because there were definable inflows and outflows (Figure 10a-d). The wetland has serious water quality problems, with only NO_3^- being removed consistently from the water column; however, the initial concentration of NO_3^- was very high at 6.58 mgl^{-1}. The other nutrients, NH_4^+, SRP, and Fe^{++}, increased as water flowed through the wetland, with serious problems in NH_4^+ levels, which increased over 100% from inflow to outflow.

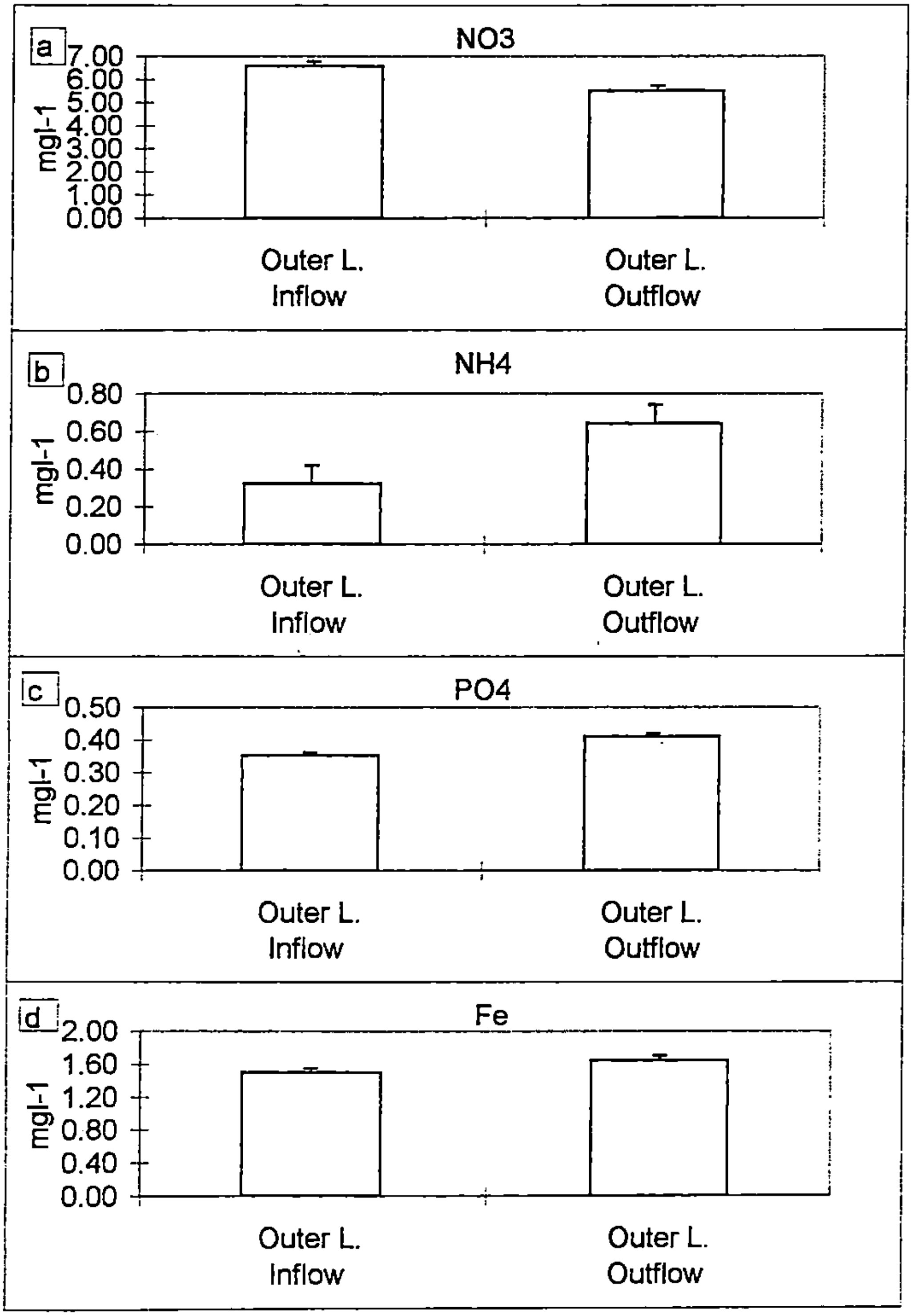


Figure 10a-d. Water quality enhancement for Outer Loop constructed wetland.

4.3.2.3 Soils

The average organic content of the soil at the Outer Loop Wetland was just under 11%, the highest of any wetland studied (Figure 3). The high organic content of the soil was well within the reference standards for a forested wetland; however, the organic content of the soil will probably remain the same based on the present vegetation at the site.

The proximity of the wetland to a landfill prompted the testing of the soil for heavy metals (Pb^{4+}, Cd^{++}, Cu^{++}, and Zn^{++}). The results are shown in Table 7. Zn^{++} was not detectable in any of the soil present in the wetland. The levels of the other metals were fairly high and could be toxic to some plants.

4.3.2.4 Plant Diversity

Outer Loop had the highest percentage (100%) of species found that were Facultative Wet to Obligate (Figure 4). This would be expected because the site was completely inundated during every visit, except for October, which would preclude any hydric intolerant plants from establishing at this site. The vegetation at this site is composed primarily of cattails (*Typha* sp.), spikerush (*Eleocharis* sp.), great bulrush (*Scirpus validus*), and water plantain (*Alisma subcordatum*). Great bulrush had the highest IV, 195, with spikerush having the second highest IV, 45.4. The main tree species found at the site was bald cypress (*Taxodium distichum*); maples (*Acer* spp.) were the only other tree species observed. Individuals of both tree taxa were

Table 7. Heavy metals in soil at Outer Loop constructed wetland.

Location	Cd mg g^{-1}	Cu mg g^{-1}	Pb mg g^{-1}
Left Lane Light	77	.86	361
Left Construction Area	77	.40	378
Right Transect 50m	77	.34	414
Right Transect 100m	90	.30	521

relatively small, with an average height between 1m-1.5m and a diameter between 2cm-5cm, which precluded doing point quarters analysis for this wetland.

The site has been invaded by cattail (*Typha* sp.) which dominates the entire western portion of the wetland. The vegetation results from Outer Loop indicate that the site has not yet achieved the goals of restoring and enhancing a bottomland hardwood forest.

4.3.2.5 Insect Diversity

Eighty-one insects representing 27 genera were observed at the Outer Loop site. The number of individuals was the third highest overall and the number of genera was tied for second highest. The Shannon Diversity Index for insects at the Outer Loop site was 1.05, which was the second highest among wetlands studied (Figure 5). The habitat classification of the insects is shown in Figure 6. The Outer Loop wetland had 19% of all individuals identified as being typically found in wet areas. The percentage was considerably lower than anticipated considering the continual inundation of the wetland.

4.3.2.6 Bird Diversity

Eighty-five birds representing 8 species were observed at the Outer Loop wetland (Table 6). The Shannon Diversity Index for birds at the Outer Loop site was 0.56, which places it next to last among the wetlands studied (Figure 7). The habitat classification for the birds at Outer Loop is shown in Figure 8. Outer Loop had 72%

of all birds identified being found typically in wet areas, which was second overall, and would be expected because of the constant inundation.

4.3.3 *Overall Review*

The Outer Loop site would be classified as a wetland based on the hydrology, the organic content of the soil, and plant composition. The site, however, would not be classified as a bottomland hardwood forest, but rather as a cattail marsh; therefore, the site does not meet any of the criteria needed to be deemed a success. The goal of creating a bottomland hardwood forest at this site is far from realization and perhaps is not possible.

Site assessment was conducted prior to the reconversion of the wetland to a wet meadow. The reconversion was being conducted to decrease the number of birds near the airport. The reconversion of the wetland may decrease the present abundance of waterfowl at this site.

4.4 **Bardstown Constructed Wetland**

The Bardstown constructed wetland is located in Nelson County. The site is bordered on the north side by U.S. Route 62 and State Route 61, on the east by State Route 52, on the south by Beech Fork Creek, and on the west by Beech Fork Creek and a store. The Bardstown site is the off-site mitigation area for bottomland hardwood areas being destroyed at the Outer Loop landfill location.

4.4.1 *Proposed Mitigation*

The restoration project included hydrologic and vegetation restoration to increase and enhance wildlife habitat (Hudson property mitigation plan).

4.4.1.1 Hydrology

Hydrologic restoration was accomplished by grading activities that eliminated all drainage structures in the northern two-thirds, while in the southern one-third grading activity was limited to the non-forested areas. Hydrology of the wetland was precipitation driven in the northern two-thirds with the southern third receiving hydrologic inputs from Beech Fork during flooding events. Three shallow ponds were created in the southern one-third to enhance and increase habitat diversity.

4.4.1.2 Plantings

Vegetation restoration included establishment of a bottomland hardwood forest over the entire site along with planting of emergent species in and around the created ponds. The three created ponds were planted with emergent and inundation tolerant species such as spikerush *(Eleocharis* sp.*)*, sedges *(Carex* spp.*)*, bulrush *(Scirpus* sp.*)*, beggarticks *(Bidens* sp.*)*, and cutgrass *(Leersia* sp.*)*. Wild millet *(Echinochloa muricata)* and similar species were also planted within the littoral shelf along the perimeter of the ponds.

Reforestation for the whole site was divided into two large planting zones.

•Zone A is approximately 82 ha. (204 ac.), the northern two-thirds, which was covered by hydric soils. The poorly drained soils were planted with species that are tolerant of wetland conditions including pin oak *(Quercus palustris)*, swamp chestnut oak *(Quercus michauxii)*, black gum *(Nyssa sylvatica)*, bitter pecan *(Carya aquatica)*, green ash *(Fraxinus pennsylvanica)*, and river birch *(Betula nigra)*. An approximately 20 ha. (50 ac.) area in the center of Zone A was planted with acorns, instead of saplings, at a density greater than 270 acorns per acre. This density allowed for germination failure and seedling mortality. This area was to serve as an experimental planting site to compare reforestation success of acorn plantings to sapling plantings.

•Zone B was an area of approximately 34 ha. (84 ac.) in the southern one-third of the wetland site. This area was composed of non-hydric floodplain soils. Zone B was planted with hydrophytic species including red maple *(Acer rubrum)*, shumard oak *(Quercus shumardii)*, bur oak *(Quercus macrocarpa)*, cottonwood *(Populus deltoides)*, persimmon *(Diospyros virginiana)*, and sweetgum *(Liquidambar styraciflua)*. The saplings were two to three feet tall and were planted on 10' centers resulting in 430 saplings per acre, with a five year goal of having 270 trees per acre or 80% survival.

4.4.1.3 Wildlife Enhancement

Wildlife enhancement consisted mainly of management for wood ducks. Placement of 10 wood duck boxes, installed at suitable intervals throughout the wetland restoration area, provided immediate nesting sites for wood ducks. The open water area interspersed with woods and emergent vegetation provided increased habitat for a variety of wading birds and waterfowl. The open water areas were designed to increase habitat for wood ducks and create a resting area for migratory populations of other bird species.

4.4.1.4 Goals

The goals were described as the completion and success of the hydrologic and vegetation restoration, including wildlife enhancement for the entire site.

4.4.2 *Assessment of Mitigation*

4.4.2.1 Hydrology

The Bardstown site has adequate inflow for proper hydrology (Table 5); however, the site lacked standing surface water in June, July, and October, but the constructed ponds did contain water in March. Beech Fork flooding events were not sufficient to provide inflow to the whole site and added minimally to the lower third of the wetland.

The goal of restoring wetland hydrology to this area has not been met. Despite adequate precipitation inflow, the elevation change from the upper 2/3 to the lower 1/3, as well as the non-hydric soils, are precluding the establishment of wetland hydrology at the site. Compounding the elevation change is the lack of noticeable grading activities that were supposed to have occurred. Additionally, various tiles and culverts were observed that could drain water away from the mitigation area.

4.4.2.2 Soils

The average organic content of the soil at the Bardstown site was the lowest among wetlands studied (Figure 3). The average for Bardstown was 5.42%, which is well below reference standards for bottomland hardwood forest soil organic content. The maximum soil organic content for the entire site was 9.04%, which is still lower than reference standards.

4.4.2.3 Plant Diversity

Bardstown had the second lowest percentage of herbaceous species classified as Facultative Wet to Obligate with 47% (Figure 4). Path rush (*Juncus tenuis*) had the highest IV (113) of all herbaceous species identified; however, it was usually found only in the extremely wet areas. Much of the wetland was covered by various grass species and millet (*Panicum* sp.) which had an IV of 13.7. The lack of species that would be considered hydrophytic suggests that the hydrology of the area is not appropriate for hydrophytic growth.

No trees measured were Facultative Wet to Obligate (Figure 11). Many of the planted saplings did not meet the minimum criteria for measurement in this study. Although Bardstown had no wetland species measured in this study, one should not interpret this to mean that wetland species do not exist on site. The random method of selecting sites for point quarters might have resulted in atypical results. At Bardstown, there are species such as *Populus deltoides* present, which were not selected during

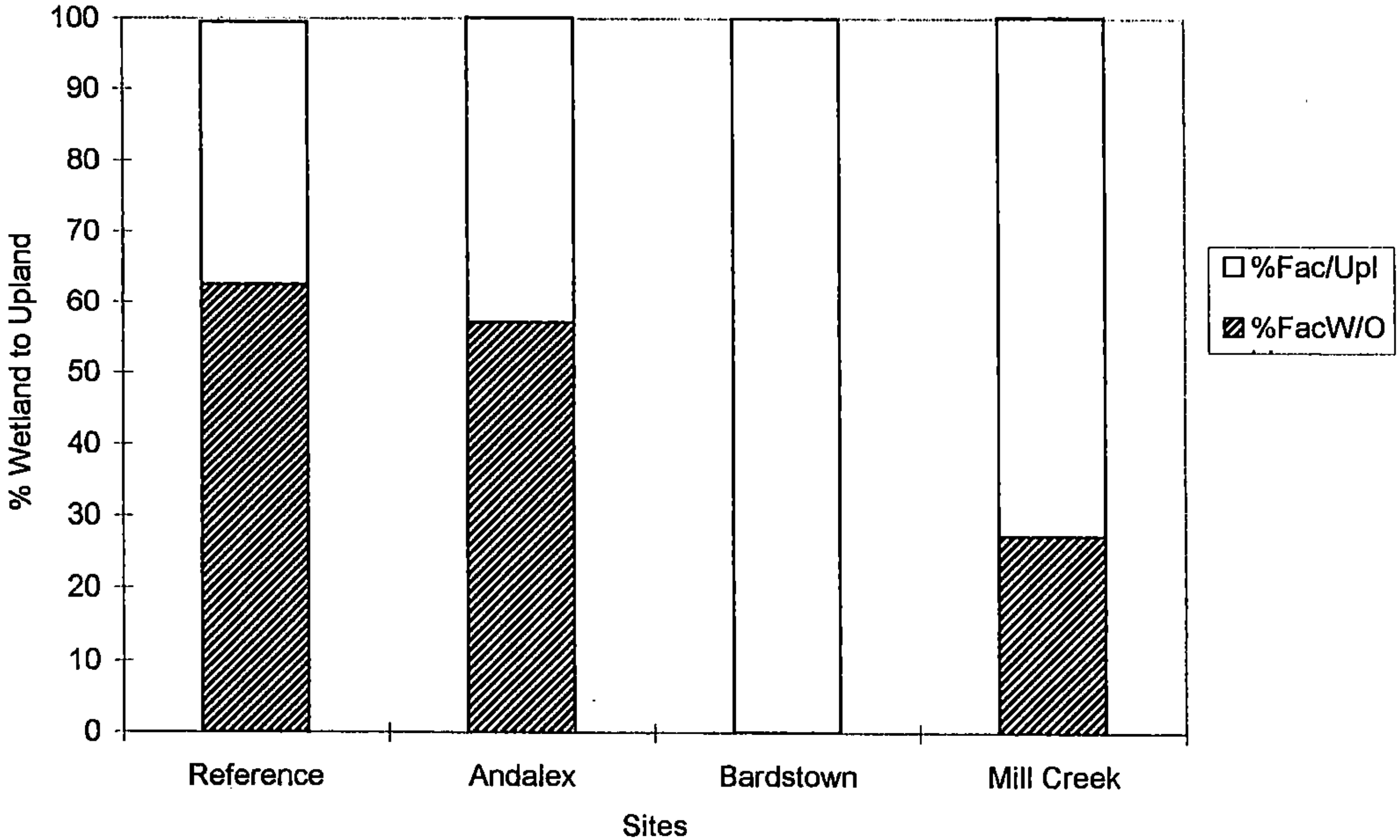


Figure 11. Wetland classification of woody vegetation for six constructed wetland in central and western Kentucky

the vegetation sampling; however, these species are restricted to a narrow zone along Beech Fork.

4.4.2.4 Insect Diversity

Seventy-six insects representing 17 genera were found at the Bardstown site, which was the lowest total of individuals and the second lowest number of genera. The Shannon Diversity Index for insects at the Bardstown site was the highest of all sites at 1.06 (Figure 5). The habitat classification of the insects at Bardstown is shown in Figure 6. Twelve percent of all insects identified are typically found in wet habitats.

4.4.2.5 Bird Diversity

The Bardstown site had the highest number of birds counted with 251, representing 17 species (Table 6). This high number would be expected considering the large size of the wetland. The Shannon Diversity Index for birds was 0.66, which was second highest overall (Figure 7). The diversity was reduced because almost 50% of the total individuals identified belonged to one species--Redwing Blackbirds.

The habitat classification for birds at the Bardstown site is shown in Figure 8. Sixty-four percent of all birds identified are typically found in wet areas, which was fourth among wetlands studied.

The duck boxes that were to be placed in the wetland were not present in March, but were present in June. This means that the site had been completed for some time before the boxes were put in place. A main problem with the boxes was their placement over ponds that were only filled in March following a flooding event.

The boxes would only have been usable during the March visit when the ponds were full, but the boxes were not present. Once the boxes were installed the ponds were dry, which would preclude wood ducks from utilizing the boxes. The goal of enhancing habitat for wood ducks is not being met at this time, mainly because of poor hydrology at the site.

4.4.3 *Overall Review*

The Bardstown site could not be classified as a wetland at present. Hydrology at this site is, at best, marginal for a wetland, evidenced by the ponds being dry in June, July and October. The ponds that were to be constructed are shown on topographic maps dated prior to mitigation processes, although there is evidence of enhancement surrounding the ponds (e.g. dams, dikes, and drainage areas). The soil is well below reference standard and it is unlikely that the organic content will change based on the plant communities present. The site does have some wetland plants and trees; however, the herbaceous vegetation is still not adequate to be considered typical of natural wetlands, and all trees that would be classified as wetland are located only in a narrow band along Beech Fork.

The selection of this site for a mitigation project is questionable. Areas near the mitigation area were flooded during the March visit. If the upper section of the mitigation site was to flood, then the roads surrounding the site would also be flooded. There was no evidence of persistent flooding of the roads.

The majority of this site will not, based on present hydrology, geology, and morphology, become a bottomland hardwood forest. There are too many unsatisfactory conditions at the site to allow for the progression to bottomland hardwood forest habitat.

4.5 **Mill Creek Restored Wetland**

Mill Creek mitigation/restoration project was designed to compensate for the loss of wetland function resulting from construction at the Louisville/Jefferson County Regional Airport. The site is located in Jefferson County, Kentucky, and is bordered on the north by Greenwood Road, on the east by a housing development, on the south by Johnstown Road, and on the west by State Route 1934.

4.5.1 *Proposed mitigation*

Mitigation was conducted primarily on the east side of Mill Creek and consisted of restoring hydrologic functions in this area. In addition, enhancement of wetland functions in areas of the site that did not presently exhibit wetland functions were also undertaken (Mill Creek mitigation plan).

4.5.1.1 Hydrology

The hydrology on the east side of Mill Creek has been changed due to past land use along with ditching and tiling. The disturbed areas were restored by redirecting tiles and ditches, and using adjustable check dams, if possible, to obtain better hydrologic conditions. This expedited the re-establishment of a bottomland hardwood forest in the area. The area of restoration was approximately 16 ha. (35-45 ac.) of the total mitigation site. Nearly 5 ha. (12 ac.) of the floodplain were mature bottomland hardwood forest. This area was preserved and protected, and was used as a seed source for the restoration areas.

4.5.1.2 Plantings

Vegetation restoration consisted of planting woody species including pin oak (*Quercus palustris*), willow oak (*Quercus phellos*) , southern red oak (*Quercus falcata*), shellbark hickory (*Quercus laciniosa*), green ash (*Fraxinus pennsylvanica*), sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), persimmon (*Diospyros virginiana*), silky dogwood (*Cornus amomum*), swamp chestnut oak (*Quercus michauxii*), and overcup oak (*Quercus lyrata*). Saplings were planted at a frequency of 430 trees/acre.

Several small ponds were to be constructed to help enhance habitat diversity. The edges of the ponds were to be planted with a mixture of hydrophytic shrub taxa such as buttonbush (*Cephalanthus occidentalis*) and alder (*Alnus* sp.), while herbaceous taxa such as bulrush (*Scirpus* sp.), smartweed (*Polygonum* sp.) , duck potato (*Sagittaria rigida*) , and pondweed (*Potamogeton* sp.) were seeded in and around the created ponds.

The west side of Mill Creek comprised approximately 80-140 acres of the total site and was used as a planted mitigation site many years ago. Portions of this area were currently non-forested and were covered by non-wetland plant species. This area was planted with native wetland species to enhance wetland function.

4.5.2.3 Wildlife Enhancement

Placement of duck, owl, and bat boxes throughout the entire mitigation area was to be part of the wildlife enhancement. The boxes were a replacement for the lack of habitat for cavity nesters at present. The mitigation site was to also serve as refuge for wildlife in the middle of an urban area.

4.5.2.4 Goals

The main objectives were to improve water quality from urban runoff, increase urban wildlife habitat, and provide recreational and educational opportunities in a metropolitan area.

4.5.2 *Assessment of Mitigation*

4.5.2.1 Hydrology

The Mill Creek site had a hydrologic budget that resulted in no net gain or loss of water throughout the year (Table 5). Mill Creek, despite this, was continuously inundated throughout the course of this study. This suggests that the site should have hydric soil composition which is retaining the water in this wetland.

The east side of Mill Creek had extensive bottomland hardwood forests prior to the mitigation effort; therefore, the hydrology of the area did not need any construction activities to improve it. The hydrology of the area is consistent with the proposed mitigation for this site.

4.5.2.2 Water Quality Enhancement

Water quality enhancement was also studied at this site to determine what effect, if any, the wetland was having on urban runoff. The wetland was only able to reduce SRP successfully, while all of the other nutrients increased from inflow to outflow (Figure 12a-d). At present, the wetland is being overloaded with nutrients from urban runoff and is unable to successfully remove them.

4.5.2.3 Soils

The average soil organic matter for the Mill Creek wetland was slightly higher than 8% (Figure 3). This is below reference standard for a bottomland hardwood forest; however, the low average maybe due to taking soil samples in recent construction areas. The soil samples taken in the mature bottomland hardwood forest area had higher organic content with a maximum of almost 16% and a low of 12%--both of which are at or near reference standards.

The undisturbed soil in the older bottomland hardwood forest portions of this wetland are already at or above reference standards. It is likely that much of the newly developed area will also have higher soil organic content in the future.

4.5.2.4 Plant Diversity

Mill Creek had 66% of all herbaceous species identified being Facultative Wet to Obligate, with 34% percent of all species identified classified as Facultative to Upland (Figure 4). Twenty-seven percent of all woody taxa identified at the site are

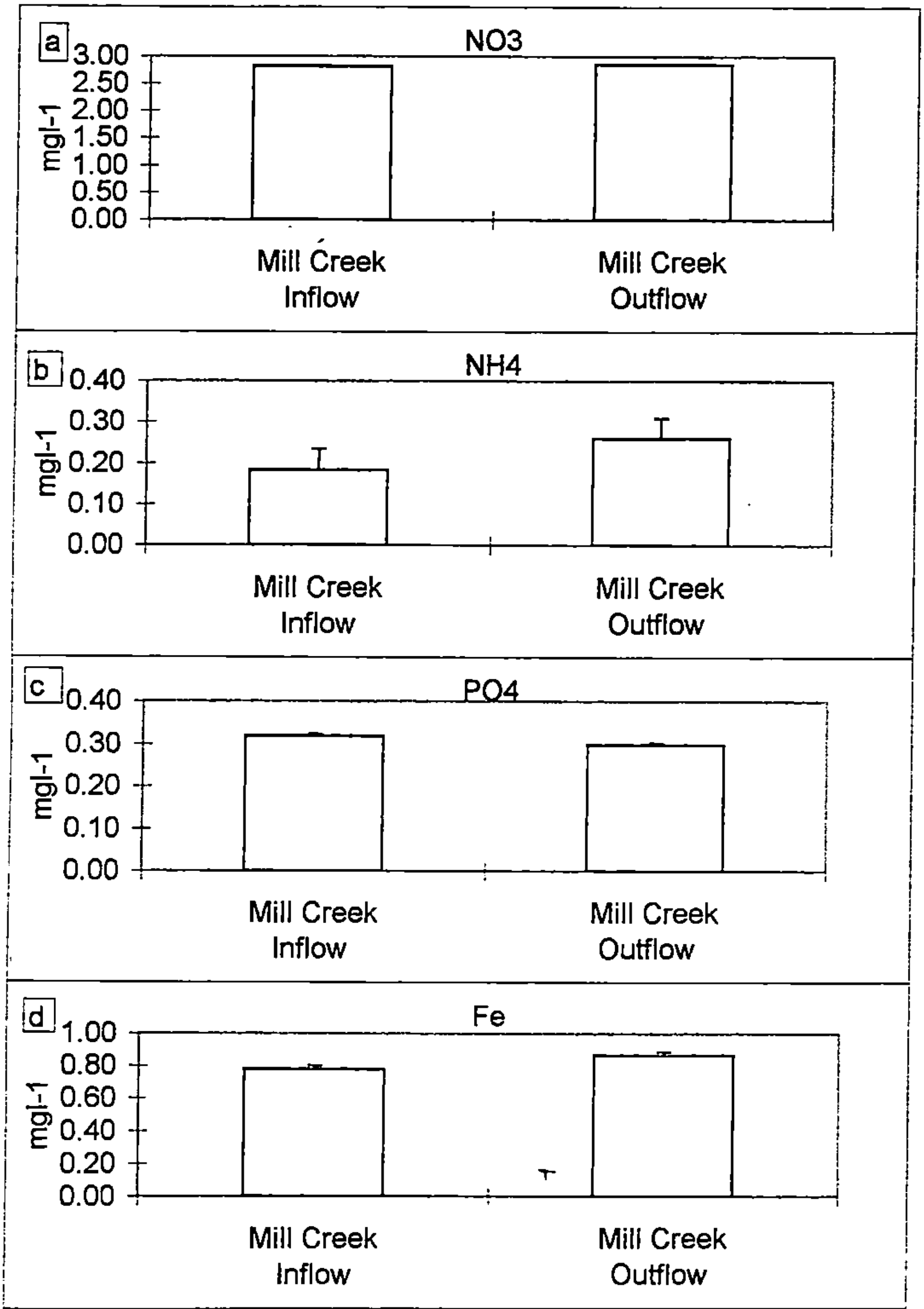


Figure 12a-d. Water quality enhancement for Mill Creek restored wetland.

Facultative Wet to Obligate, which is lower than expected (Figure 11); however, many of the trees identified at this site are classified as Facultative.

The present herbaceous and woody vegetation at the Mill Creek site is similar to reference standard for bottomland hardwood forest and will probably include more wetland species in the future, if the site is undisturbed. The dominant woody vegetation on the west side of Mill Creek was red maple (*Acer rubrum*) with an IV of 0.97 and birch (*Betula* sp.) with an IV of 0.53. Red maple (*Acer rubrum*) also had the largest relative dominance (RD) with 0.31. The dominant woody vegetation on the east side of Mill Creek was birch (*Betula* sp.) with an IV of 1.7 and red maple (*Acer rubrum*) with an IV of 0.62. Birch (*Betula* sp.) also had the largest relative dominance on the east side with a RD of .58.

4.5.2.5 Insect Diversity

The Mill Creek site had the highest number of insects collected with 211 and the highest number of genera with 35. Shannon Diversity Index for insects at the Mill Creek site was 1.00 (Figure 5). Insect habitat classification for the Mill Creek site is shown in Figure 6. Eleven percent of all insects identified at this site are typically found in wet areas. Mill Creek was the only site that had insects identified typically found in wooded areas (9%). This is important since all mitigation projects are supposed to be bottomland hardwood forests.

4.5.2.6 Bird Diversity

Eighty-seven birds representing 16 species were identified at Mill Creek, which was the highest number of species among wetlands studied (Table 6). Shannon Diversity Index for birds at the Mill Creek site was 0.97, which was also the highest among the wetlands studied (Figure 7). The habitat classification for birds at the Mill Creek site is shown in Figure 8. Sixteen percent of the observed species are typically found in wet areas.

The high bird diversity and low wetland bird percentage for Mill Creek is probably due to the surrounding urban area. Many birds typically not found in wet areas use this area as a habitat refuge. The Mill Creek site did, however, have obligate wetland birds such as Black Crowned Night Heron and Green Back Heron, that were not found at any of the other sites.

4.5.3 *Overall Review*

The Mill Creek site could be classified as a wetland. The hydrology and geology of the site were typical of a wetland habitat prior to mitigation, therefore minimal construction was needed to enhance the site. The herbaceous plant community is split between field species where construction has taken place, and hydrophytic species located in the inundated areas of the wetland. The woody vegetation at Mill Creek obviously is capable of withstanding temporary inundation, despite a low percentage being classified as Facultative Wet or Obligate.

The Mill Creek site has portions that could already be classified as a bottomland hardwood forest; however, the new mitigation areas will take some time to achieve bottomland hardwood forest status. One potential problem for this wetland is the current housing construction at the very edge of the wetland along with the construction of a road through the wetland, which has destroyed a section of well developed bottomland hardwood forest. This development could add more nutrients to an already stressed habitat and further decrease the ability of the wetland to remove nutrients from the water column.

4.6 **Andalex Constructed Wetland**

The Andalex mitigation area is located near Madisonville in Hopkins County, Kentucky, in the Pond River floodplain. Two sections make up the Andalex mitigation area. The western site was bordered by a railroad on the north side, by an abandoned rail spur on the west, an explosives storage area on the east, and bottomland hardwood forest on the south. The eastern site was bordered on the north by a railroad and farmland, on the east by prior converted farmland, on the south by prior converted farmland and a hill, and on the west by a hill and a county road.

4.6.1 *Proposed Mitigation*

The proposed mitigation for the Andalex wetland was designed to compensate for the loss of wetland function due to mining activities (Andalex mitigation plan).

4.6.1.1 Hydrology

The hydrology of the area was driven mainly by precipitation, however, there are occasions of overbank flooding from the Pond River. The agricultural alteration of the hydrology consists mainly of ditches that were used to drain excess water, no tile system was in place in the mitigation area. As a part of the wetland restoration process the ditches were plowed and filled to stop the drainage of water away from the area thereby establishing a wetland hydrology. The large drainage ditch was to be graded to form a natural non-channelized flow pattern.

4.6.1.2 Plantings

The mitigation area was previously used for agricultural purposes for many years. Much of the area had already been planted with trees as part of advanced mitigation by Andalex. The main trees that were planted are oak (*Quercus* spp.), hickory (*Carya* spp.), and bald cypress (*Taxodium distichum*.). Overstory species such as red maple (*Acer rubrum*), sycamore (*Platanus occidentalis*), sweet gum (*Liquidambar styraciflua*), and green ash (*Fraxinus pennsylvanica*) were not planted because they usually colonize by themselves. Planting was accomplished by both mechanical and hand planting, using seedlings and nuts. The mixture of species did not allow for more than 100 stems/acre of any one species, this rate was adjusted based on site characteristics and availability. Herbaceous plant species were not planted as part of the mitigation effort.

4.6.1.3 Goals

Stated goals for success by Andalex include the establishment of a diverse species mixture of trees, where a single species was not dominant (i.e. not greater than 300/acre). Another stated goal was the ability of the soil at the site to exhibit hydric characteristics (e.g. soil saturation for 14 day period during growing season). The area was inundated or saturated within 12" of the surface for a minimum of 11 days during normal growing season.

4.6.2 *Assessment of Mitigation*

Both sections of the Andalex site were to be restored similarly, so discussion of assessments will combine the results from both sections.

4.6.2.1 Hydrology

Andalex has adequate inflow for wetland hydrology (Table 5). The Andalex wetland was flooded during the visit in March except for about a 6-10 acre section that was not inundated by the Pond River. The wetland site was devoid of water at the inflow in July, and lacking water at the inflow and outflow in October. The absence of water for a long portion of the year suggests that the soil of the site is not hydric and will probably not retain moisture.

4.6.2.2 Water Quality Enhancement

Water quality enhancement was also measured for this wetland (Figure 13a-d). The wetland successfully reduced all nutrients except for SRP, which increased 16%

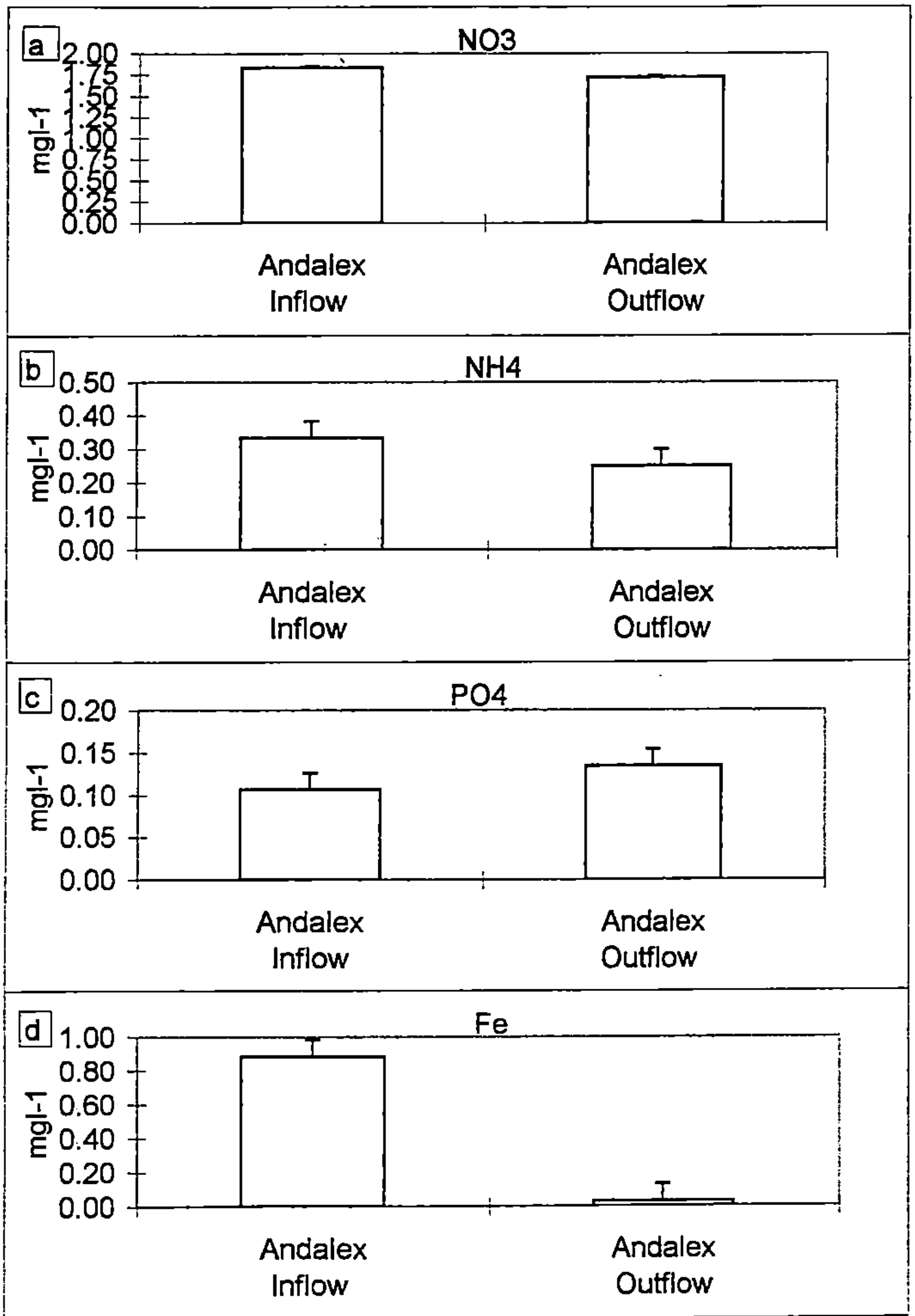


Figure 13a-d. Water quality enhancement for Andalex constructed wetland.

from inflow to outflow. The dramatic decrease in Fe^{++} is probably due to the extremely high readings obtained at the inflow on two visits.

4.6.2.3 Soils

The average soil organic content for the Andalex site was 7.1%, which was next to the lowest of all wetlands studied (Figure 3). This average organic content is below reference standards and would not be considered typical of natural wetlands. The highest organic content of any soil sample at this site was 8.59%, which is still too low for a site to be considered a wetland.

4.6.2.4 Plant Diversity

Andalex had the lowest percentage of herbaceous vegetation classified as Facultative Wet to Obligate with 39% (Figure 4). The low number of species that would be considered hydric suggests that the hydrology and soil of the area are not adequate to support hydrophytic growth. The highest IV for herbaceous plants were 0.74 for path rush (*Juncus tenuis*) and 0.46 for Johnson grass (*Sorghum halepense*). Andalex was similar to the reference sites with 57% of the trees measured being Facultative Wet to Obligate and with 43% being Facultative to Upland (Figure 11). The highest RD for woody vegetation was 0.44 for sugar maples (*Acer saccharum*). All trees measured for this study were all part of the medium to old growth forest surrounding the site. None of the planted saplings were used because they did not meet the minimum requirements of this study.

The woody vegetation at the site was similar to that found in reference wetlands; however, the main areas of trees were in narrow bands encompassing the wetland and bordering the ditch that flows along the western edge of the wetland. The eastern section of the wetland has no medium to old age trees, only those saplings planted as part of the mitigation procedures were present, with a majority still not exceeding 2m in height.

4.6.2.5 Insect Diversity

At Andalex 133 insects representing 22 genera were identified. The Shannon Diversity Index for insects at the Andalex site was 0.7, which was the lowest of all wetlands studied (Figure 5). The habitat classification of the insects for the Andalex site is shown in Figure 6. Fourteen percent of insect taxa identified are typically found in wet areas, with none typically found in wooded areas.

4.6.2.6 Bird Diversity

Andalex had 15 birds representing 4 species (Table 6). These numbers were extremely low considering the large area of the wetland. There were other birds identified on different occasions, but not while walking the transect for the bird diversity study. The Shannon Diversity Index for birds at the Andalex site was .57 (Figure 7). Habitat classification of the birds at the Andalex site is shown in Figure 8. Twenty-seven percent of individuals identified are typically found in wet areas.

4.6.3 *Overall Review*

The Andalex site would jurisdictionally be classified as a wetland; however, it would not be classified as a wetland functionally. The hydrologic and soil problems at this site are presently preventing it from attaining success; however, the sites location adjacent to the Pond River would suggest proper hydrology could be reestablished. The lack of herbaceous vegetation typically found in wetlands may be a result of the hydrologic problems. The site does have a sufficient seed base for woody vegetation on site and this base will likely be the source of material for reforestation throughout the site. One other advantage the site has is the proximity to the Pond River, which could help out significantly with the hydrology problems if flooding events are frequent.

The area surrounding the site is primarily bottomland hardwood forest and this will eventually convert the mitigation area. The Andalex site will probably become a bottomland hardwood forest, but it will mainly occur naturally and with little help from the mitigation efforts.

5.0 Conclusions Based upon the Assessment of Mitigation Projects

5.1 Success of projects

The six constructed wetlands all had problems meeting the requirements described in the proposed mitigation plans. The primary problem was proper wetland hydrology not being successfully restored to the wetlands. Wetland restoration failures are primarily caused by improper hydrology (Bedford, 1996). This was similar to a problem in south Florida where a majority of the wetlands restoration failures were due to improper or inadequate hydrology (Erwin, 1991). Problems with hydrology at Carrollton, Bardstown, Outer Loop, and portions of Andalex can be linked to the absence of a nearby river or stream, which is usually the main inflow for a bottomland hardwood forest (Bedford, 1996). It should be noted that the Mill Creek, Henderson, and parts of Andalex sites were located near a river or stream and had wetland hydrology.

Water quality enhancement, for all wetlands with definable inflows and outflows, was another hydrologic problem. Each of the four sites where water quality enhancement should have taken place had problems with removing nutrients from the water column.

Another problem that most sites had was with organic content in the soil. Only the Carrollton and Outer Loop site had organic soil content similar to the reference standard. The low organic averages indicate that the soils at the sites were not similar to natural swamps (Tiner, 1993). The average obtained for most sites was similar to the average of 6.2%, reported for created wetlands (Manchung et al., 1996). Improper soil will not only affect the hydrology, but will also have an effect on the plant communities inhabiting each site. This is evident when looking at the wetland classification of the vegetation for most sites (Gleeson and Tilman, 1990; Bridgham and Richardson, 1993).

The proposed mitigation plan for each site was to restore or construct a bottomland hardwood forest. With the exception of the Henderson site, which had phenomenal sapling growth, the goal of restoring bottomland hardwood forest habitat would not be considered successful in any of the sites where saplings were planted. Mill Creek had areas of mature forest so establishment of a bottomland hardwood forest was not necessary for this site. Andalex and Bardstown both had areas of mature forest, but these areas were primarily restricted to small corridors and isolated groves throughout the sites. This is similar to the results that Perry et al. (1997) obtained from a constructed wetland where the mortality rate was 35% and most woody growth came from volunteer species and not from planted saplings.

The herbaceous vegetation at each site would not be classified as being typical of a wetland, with the exception of the Outer Loop site. The Outer Loop site had 100% of all herbaceous vegetation being Facultative Wet or Obligate, which would be expected since the site was inundated for most of the study period. The other sites did not have large percentages of hydrophytic plants, which may be a result of improper soil. It has been shown that the soil of an area affects plant succession; therefore if the soil is not hydric, moisture will not be retained and hydrophytic plants will not be able to grow (Gleeson and Tilman, 1990).

Bird and insect populations had varying ranges of diversity and habitat classification. The bird diversity for the mitigation sites was not extremely high except for Mill Creek, which had a very diverse bird population. A majority of mitigation sites had over 50% of birds identified as being typically found in wet areas. Insect diversity for the mitigation sites was much higher than the bird diversities. None of the wetlands had >25% of the insects identified being typically found in wet areas, and only Mill Creek had any insects typically found in wooded areas.

5.2 Future Success of the Mitigation Sites

It appears that two of the six constructed wetlands, Mill Creek and Henderson, will be successful in the future and become bottomland hardwood forests. The likelihood of the entire Andalex site becoming a bottomland hardwood forest is marginal, but portions of the area have the potential to become a wetland. The Carrollton, Bardstown, and Outer Loop sites will probably not become bottomland hardwood forests in the future. It is likely that the Carrollton site will have more upland tree species on site than wetland species, because of the problems with various components of the site. The Bardstown site is basically a field with saplings planted in it. The upper 2/3 of this site will probably never become a bottomland hardwood forest. The lower 1/3 could become a bottomland hardwood forest, but mainly due to the natural progression of the field back to a forest. The probability of success for the

Outer Loop site is not good--this site has problems with hydrology, human interference, and increased levels of contaminants in the soil, which will inhibit plant growth.

6.0 Recommendations for Future Bottomland Hardwood Forest Restoration Projects in central and western Kentucky

6.1 Site Selection

The most critical component for successful bottomland hardwood forest restoration is proper hydrology. Results of this study suggest that sites not located near rivers or streams will not be successful and that the mitigation effort will be wasted. Wetlands that were determined to be successful now or to become successful in the future in this study had excellent site location. All of the successful sites were near rivers or streams that provided inflow from flooding events and helped to maintain high groundwater levels.

Future swamp mitigation sites should be located near or adjacent to a river or stream. Prior to granting a permit for wetland destruction and subsequent restoration or construction of another wetland, the site location should be examined to ensure that it is appropriate for the mitigation to be conducted. If the proposed mitigation site is not appropriate, then the permit should not be granted until a suitable site can be located.

6.2 Temporal Problems

The extensive amount of time needed for woody vegetation growth (e.g. cypress trees grow 12 in. in diameter every 100 years) will always be a major problem with restoration projects (Ewel and Odum, 1984). Because of a long time scale the actual success of a restored bottomland hardwood forest cannot be determined 5, 10, even 15 years after construction is completed. For this reason it is recommended that the HGM be used only to determine the appropriate size and type of wetland to be restored or constructed, and not to assess the success of the restored wetland, until the restored site has reached maturity.

6.3 **Designed versus Self-Design**

Studies such as Perry et al. (1997), showed that wetlands with designed plantings take several years for wetland plants to start growing. These wetlands also display higher mortality rates (35%) in woody vegetation than any of the proposed mitigations had set for success (<20%). Because of the results obtained from designed wetland plantings, the self-design process described by Mitsch and Wilson (1996) is recommended for future mitigation projects.

In a self-designed wetland as many species as possible are introduced, with the knowledge that nature will determine the species most suited for the environment (Mitsch and Wilson, 1996). This approach also acknowledges the importance of species naturally colonizing a wetland (Mitsch and Wilson, 1996). A recent study comparing these two methods demonstrated that the planted self-design sites had high diversity and species richness, with lower percentages of nuisance species such as *Typha* sp. than the naturally colonized wetlands (Rienartz and Warne, 1993).

6.4 **Mitigation Banking**

Mitigation banking is recommended as a reasonable way to compensate for the loss of wetland function due to construction activities. Mitigation banking is the use of large off-site wetland areas to mitigate for several independent wetland development conversions (Environmental Law Institute, 1993). Because of the long time periods needed for bottomland hardwood forests to become mature, mitigation banking is an effective way of preventing the loss of valuable bottomland hardwood forest areas that already exist. One recommendation would be to buy or set aside large areas of swamp and bottomland hardwood forest habitat to allow for the preservation of these areas. The area surrounding the Henderson location would be ideal for this type of mitigation banking as it already has large tracts of swamp and bottomland hardwood forest.

6.5 The Future of Mitigation

It has been shown that the mitigation procedures presently used are not satisfactorily restoring wetland ecosystem functions. The methods used to measure these functions also need to be re-evaluated to better establish the status of created wetlands. Drastic changes in mitigation procedures will need to be made quickly if the practice of wetland mitigation is to accomplish the goal of "no net loss".

Literature Cited

Bedford, B. L., 1996. The need to define hydrologic equivalence at the landscape scale for freshwater wetland mitigation. Ecological Applications 6(1), 57-68.

Blood, E. R., 1980. Surface water hydrology and biogeochemistry of the Okefenokee Swamp watershed. Ph.D. Dissertation, University of Georgia, Athens. 194pp. In Taylor et al., 1990. Bottomland hardwood forests: their functions and values. Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis, Chelsea, Michigan.

Brady, N. C., 1990. The nature and properties of soils. Macmillan, New York, New York.

Bridgham, S. D. and C. J. Richardson, 1993. Hydrology and nutrient gradients in North Carolina Peatlands. Wetlands 13(3), 207-218.

Brinson, M. M., 1993. A hydrogeomorphic classification for wetlands. Wetlands Research Program Technical Report WRP-DE-4. U.S. Army Corps of Engineers Waterways Experiment Station. Vicksburg, Mississippi, USA.

Brinson, M. M. and R. Rheinhardt, 1996. The role of reference wetlands in functional assessment and mitigation. Ecological Applications 6(1), 69-76.

Brower, J. E., J. H. Zar and C. N. von Ende, 1990. Field and Laboratory Methods for General Ecology. W. C. Brown, Dubuque, IA. 237pp.

Burnas, B, 1967. A new method for decomposition and comprehensive analysis of silicates by atomic absorption spectrometry. Analytical Chemistry 39:1682-1686.

Conner, W. H., T. R. Huffman, and W. Kitchens, 1990. Composition and productivity in bottomland hardwood forest ecosystems: the report of the vegetation workgroup. Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems, pg. 455. Lewis, Chelsea, Michigan.

Costanza, R., S. C. Farber, and J. Maxwell, 1989. Valuation and management of wetland ecosystems. Ecological Economics 1, 335-361.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe, 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington, D.C. USA.

Cubbage, F. W. and C. H. Flather, 1993. Forested wetland area and distribution. Journal of Forestry, May, 35-40.

Dahl, T. E., 1990. Wetlands losses in the United States, 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington D.C., 21p.

Dean, W. E. Jr., 1974. Determination of carbonate and organic matter in calcareous sediment and sedimentary rocks by loss on ignition: comparison with other methods. Journal of Sedimentary Petrology 4:22-248.

Eliot, W., 1985. Implementing mitigation policies in San Francisco Bay: a critique. State Coastal Conservancy, Oakland, California, USA.

Environmental Law Institute, 1993. Wetland Mitigation Banking. Washington, D.C.

Erwin, K. L., 1991. An evaluation of wetland mitigation in the South Florida water management district. Volume I, Final report to South Florida Water Management, West Palm Beach, Florida, USA.

Ewel, K. C. and H. T. Odum, 1984. Cypress Swamps. University of Florida Presses Gainesville, Florida, USA.

Faulkner, S. P. and W. H. Patrick Jr., 1992. Redox processes and diagnostic wetland soil indicators in bottomland hardwood forests. American Journal of the Soil Science Society 56,856-865.

Gleeson, S. K. and D. Tilman, 1990. Allocation and the transient dynamics of succession on poor soils. Ecology 71(3), 1144-1155.

Gosselink, J. G. and R. E. Turner, 1978. The role of hydrology in freshwater wetland ecosystems. In Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, New York, 63-78.

Hardin, M. D., 1992. A comparison of benthic invertebrates distribution in four Ohio River basin wetlands. M.S. thesis Morehead State University, KY. 134pp.

Kuenzlar, E. J., P. J. Mulholland, L. A. Yarbro, and L. A. Smock, 1980. Distributions and budgets of carbon, phosphorus, iron, and manganese in a floodplain swamp ecosystem. Water Resources Research Institute of the University North Carolina, Raleigh. Report No. 57. In Taylor et al., 1990. Bottomland hardwood forests: their functions and values. Ecological Processes and Cumulative Impacts:Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis, Chelsea, Michigan.

Kruzynski, W.L., 1990. Options to be considered in preparation and evaluation of mitigation plans. Wetland creation and restoration: the status of the science. EPA Research Laboratory, Corvalis, Oregon, USA. 143-158.

Kusler, J. A. and M. E. Kentula, editors, 1990. Wetland creation restoration: the status of the science. EPA 600/3-89/038. Environmental Research Laboratory, Corvalis, Oregon, USA.

Kusler, J. A., W. J. Mitsch, and J. S. Larson, 1994. Wetlands. Scientific American, January 1994, 64B-70.

Manchung, L., R. P. Brooks, S. S. Yates, and K. L. Hoover, 1996. Soil properties of reference wetlands and wetland creation projects in Pennsylvania. Wetlands 16(4), 532-541.

Merrit, R. W. and K. W. Cummins, editors, 1984. An introduction to the aquatic insects of North America, Second edition. Kendall/Hunt, Dubuque, Iowa.

Mitsch, W. J., 1993. Ecological engineering-a cooperative role with the planetary life-support systems. Environmental Science and Technology 27, 438-445.

Mitsch, W. J. and J. G. Gosselink, 1993. Wetlands. Second edition. Van Nostrand Rienhold, New York, New York, USA.

Mitsch, W. J. and B. C. Reeder, 1992. Nutrient and hydrologic budgets of a Great Lakes coastal freshwater wetland during a drought year. Wetlands Ecology and Management 1(4), 211-222.

Mitsch, W. J. and R. F. Wilson, 1996. Improving the success of wetland creation and restoration with know-how, time, and self-design. Ecological Applications 6(1), 77-83.

Odum, H. T., 1989. Ecological engineering and self-organization. Ecological engineering: an introduction to ecotechnology. Wiley Interscience, New York, New York USA, 79-101.

Perry, M. C., P. C. Osenton, and C. B. Sibrel, 1997. Early vegetational changes on a forested wetland constructed for mitigation. Wetland Journal 9(2), 17-20.

Peterson, R. T., 1980. A field guide to the birds of eastern and central North America, Fourth edition. Houghton Mifflin Company, Boston, Massachusetts.

Race, M. S. and M. S. Fonseca, 1996. Fixing compensatory mitigation: What will it take. Ecological Applications 6(1), 94-101.

Redington, C. B., 1994. Plants in Wetlands. Kendall/Hunt, Dubuque, Iowa, USA.

Reed, P. B., Jr., 1988. National list of plant species that occur in wetlands: national summary. U.S. Fish and Wildlife Service, Washington, D.C. Biological

Report 88(24).

Rienartz, J. A. and E. L. Warne, 1993. Development of vegetation in small created wetlands in southeast Wisconsin. Wetlands 13, 153-164.

Taylor, J. R., M. A. Cardamone, and W. J. Mitsch, 1990. Bottomland hardwood forests: their functions and values. Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems, pg. 13. Lewis, Chelsea, Michigan.

Tiner, R. W., 1993. The primary indicators method-a practical approach to wetland recognition and delineation in the United States. Wetlands 13(1), 50-64.

Transportation Cabinet of Kentucky, 1992. Final mitigation plan for the Lambert tract. August 4th, 1992.

Walbridge, M. R., 1993. Functions and values of forested wetlands in the southern United States. Journal of Forestry, May, 15-19.

Young, P., 1996. The "New Science" of wetland restoration. Environmental Science & Technology 30(7), 292-296.

Zedler, J. B., 1996. Ecological issues in wetland mitigation: an introduction to the forum. Ecological Applications 6(1), 33-37.

Appendix A

Water Quality

Water Data

Site	Date	Location	NO3		NH4	PO4		Fe
Andalex B1	3/17/97	Inflow	0.8	0.8	0.64	0.023	0.029	0.13
Andalex B4	3/17/97	Inflow	0.9	0.8	0.2	0.02	0.02	0.19
Andalex B6	3/17/97	Outflow	0.9	1	0.029	0.02	0.02	0.23
Andelex B9	3/17/97	Outflow	0.8	0.9	0.32	0.02	0.02	0.19
	inflow average		0.85	0.8	0.42	0.0215	0.0245	0.16
	outflow average		0.85	0.95	0.1745	0.02	0.02	0.21
	% Difference		0	-18.75	58.45	6.98	18.37	-31.25
Carrollton	3/18/97	Inflow	1.2	1.2	0.55	0.23	0.21	0.28
Carrollton	3/18/97	Outflow	0.6	0.6	0.15	0.09	0.08	0.04
	% Difference		50	50	72.73	60.87	61.90	85.71
Outer Loop	3/19/97	Inflow	9.3	7.7	0.79	0.06	0.06	0.52
Outer Loop	3/19/97	Outflow	6.2	6.3	1.84	0.15	0.16	0.99
	% Difference		33.33	18.18	-132.91	-150.00	-166.67	-90.38
Mill Creek	3/19/97	Inflow	5.6	5.8	0.45	0.07	0.07	0.26
Mill Creek	3/19/97	Outflow	7.3	6	0.7	0.07	0.08	0.33
	% Difference		-30.36	-3.45	-55.56	0.00	-14.29	-26.92
Andalex	5/28/97	Inflow	3.8	3.9	0.16	0.44		3.3
Andalex	5/28/97	Outflow	3.3	3.4	0.4	0.59		2.33
	%Difference		13.16	12.82	-150.00	-34.09		29.39
Carrollton	5/27/97	Inflow	0.4	0.4	0.02	0.08		0.42
Carrollton	5/27/97	Outflow	0.6	0.6	0.01	0.26		0.93
	%Difference		-50.00	-50.00	50.00	-225.00		-121.43

Water Data

Site	Date	Location	NO3		NH4	PO4	Fe
Outer Loop	5/30/97	Inflow	1.1	1.2	0.15	0.92	3.3
Outer Loop	5/30/97	Outflow	0.5	0.5	0.08	0.99	3.3
	% Difference		54.55	58.33	46.67	-7.61	0.00
Mill Creek	5/30/97	Inflow	1.5	1.6	0.1	0.8	2.07
Mill Creek	5/30/97	Outflow	1.3	1.4	0.07	0.79	2.26
	% Difference		13.33	12.50	30.00	1.25	-9.18
Andalex	7/16/97	Outflow	1.4	1.4	0.31	0.14	0.08
Carrollton	7/14/97	Inflow	3	3.1	0	0.67	0.14
Carrollton	7/14/97	Outflow	2	1.5	0	0.31	0.06
	% Difference		33.33	51.61	0.00	53.73	57.14
Outer Loop	7/14/97	Inflow	9.7	10.5	0.02	0.37	0.68
Outer Loop	7/14/97	Outflow	9.6	10	0.01	0.34	0.66
	% Difference		1.03	4.76	50.00	8.11	2.94
Mill Creek	7/15/97	Inflow	1.2	1.2	0	0.33	0.01
Mill Creek	7/15/97	Outflow	0.7	0.4	0.01	0.25	0.01
	% Difference		41.67	66.67	0.00	24.24	0.00

Appendix B

Soils

Organic Content

Site #	1st % Diff	2nd % Diff
Owen1	10.87	1.59
Owen2	9.33	1.3
Owen3	9.22	1.2
Owen4	13.07	1.48
Owen5	8.29	1.32
Owen6	11.28	1.34
OwenAverage	10.34	1.37
STDEV	1.74	0.14
Andalex1	8.59	1.23
Andalex2	5.27	0.62
Andalex3	5.89	0.77
Andalex6	7.68	0.83
Andalex7	6.74	0.72
Andalex8	8.19	1.14
Andalex9	7.34	0.75
AndalexAverage	7.10	0.87
STDEV	1.12	0.21
Outer Loop1	11.29	1.88
Outer Loop2	7.84	1.6
Outer Loop3	12.94	1.89
Outer Loop4	8.29	1.19
Outer Loop5	10.56	2.53
Outer Loop6	11.97	1.39
Outer LoopAverage	10.48	1.75
STDEV	2.03	0.47
Slough 1	9.66	-1.12
Slough 1	17.37	0.5
Hopkins r1	8.66	-0.25
Hopkins r2	8.83	0.77
Hopkins r3	9.9	0.65
Refernce Average	10.88	0.11
STDEV	3.28	0.71

Site #	1st % Diff	2nd % Diff
Bards1	7.94	2.35
Bards2	9.04	1.67
Bards3	5.97	0.75
Bards4	5.93	0.56
Bards5	3.82	0.53
Bards6	4.15	0.41
Bards7	4.05	0.46
Bards8	5.52	0.63
Bards9	3.62	89.47
Bards10	4.12	-3.87
BardsAverage	5.42	9.30
STDEV	1.86	28.22
Mill Creek1	4.58	13.22
Mill Creek2	5.57	0.72
Mill Creek3	8.15	0.83
Mill Creek4	6	0.69
Mill Creek5	15.87	-1.35
Mill Creek6	12.61	0.2
Mill Creek7	6.53	-0.09
Mill Creek8	6.58	-0.33
Mill Creek Average	8.24	1.74
STDEV	3.94	4.70
Henderson1	9.77	2.49
Henderson2	6.99	17.43
Henderson3	8.8	1.67
Henderson4	8.38	1.77
Henderson5	7.87	3.1
Henderson6	8.02	2.55
Henderson7	9.97	2.2
Henderson Average	8.54	4.46
STDEV	1.06	5.74

Appendix C

Plants

Henderson

Species	Common Name	Classification	# Individual	% Coverage	Important Value
Salix nigra	Black Willow	Upl/Obl	6	0.1	12.4
Populus deltoides	Cottonwood	Fac/FacW	104	1.7	37
Juncus tenuis	Path Rush	Fac/FacW	11	0.17	7.4
Taxodium distichum	Bald Cypress	Obl	2	0.03	5.4
Cruciferae	Mustard plant	Unknown	16	0.3	12
Ambrosia sp.	Ragweed	Fac/FacU	35	0.6	13
Acer sp.	Maple	Fac/FacW	4	0.06	5.8
Polygonum sp.	Polygonum	Fac	16	0.3	6.8
Ulmus	Elm	Fac	4	0.06	3.8
Total			198	3.32	
Other plants				11.18	
Total Coverage				14.5	
% FacW/Obl		56			

Carrollton

Species	Common Name	Classification	# Individuals	%Coverage	Importance Value
Sorghum halepense	Johnson Grass	FacU	34	2.8	27
Juncus tenuis	Path Rush	Fac/FacW	8	0.8	12
Carex frankii	Sedge	Obl	43	4	40
Quercus sp.	Oak	Fac	1	0.08	6.6
Asclepias syriaca	Common Milkweed	Fac	19	1.5	22
Ambrosia sp	Ragweed	FacW/FacU	3	0.25	8
Setaria viridis	Foxtail	Obl/Upl	2	0.25	8
Rumex crispus	Curly Dock	FacW/FacU	2	0.25	8
Total			112	9.93	
Other plants				17.4	
Total Coverage				27.33	
% FacW/Obl		63			

Outer Loop

Species	Common Name	Classification	# Individuals	% Coverage	Importance Value
Typha sp.	Cattail	Obl	44	1.4	37
Eleocharis sp.	Spike Rush	Obl	25	1.4	45.4
Scirpus validus	Great Bulrush	Obl	253	8	195
Alisma subcordatum	Water Phantom	Obl	49	1.5	73
Total			371	12.3	
Other Plants				1.28	
Total Coverage				13.58	
% FacW/Obl		100			

Bardstown

Species	Common Name	Classification	# Individuals	% Coverage	Importance value
Juncus tenuis	Path Rush	Fac/FacW	1134	3.6	113
Sorghum halpense	Johnson Grass	FacU	20	0.047	3.8
Ambrosia sp.	Ragweed	FacW/FacU	27	0.09	11.4
Panicum sp.	Panicum	Fac	102	0.3	13.7
Elymus sp.	Wild Rye	Fac/FacU	25	0.07	3.3
Quercus sp.	Oak	Fac	5	0.01	5.5
Coronilla varia	Crown Vetch	Unknown	8	0.025	2
Allium vineale	Wild Garlic	FacU	15	0.047	6.5
Populus deltoides	Cottonwood	Fac/FacW	67	0.2	9.6
Ranunculus sp.	Ranunculus	Fac	17	0.05	3.9
Carex vulpinoidea	Fox sedge	Obl	17	0.05	5.2
Eleocharis obtusa	Short Rush	Obl	125	0.4	12.3
Artemisia sp.	Tomato-like plant		111	0.4	23.5
Cirsium sp.	Thistle	Fac	9	0.03	3.3
Carex tribuloides	Sedge	FacW/Obl	36	0.1	5.5
Juncus marginatus	Rush	FacW	16	0.05	2.7
Juncus effusus	Rush	FacW/Obl	7	0.02	1.9
Total			1741	5.49	
Other Plants				1.78	
Total Coverage				7.27	
% FacW/Obl		47			

Andalex A

Species	Common Name	Classification	# Individuals	%Coverage	Importance Value
Juncus tenuis	Path Rush	Fac-/FacW	134	2	39
Asclepias syriaca	Common Milkweed	Fac	14	0.2	9.1
Artemsia sp.	Tomato-like plant	Fac	331	5	98
Ranunculus sp.	Buttercup	Fac	9	0.13	8
Ambrosia sp.	Ragweek	FacW/FacU	21	0.3	15
Rumex crispus	Curly Dock	FacU/FacW	2	0.03	6.6
Sorghum halepense	Johnson Grass	FacU	171	2.5	46
Carya sp.	Hickory	Fac	1	0.013	3.2
Acer sp.	Maple	Fac/FacW	1	0.013	3.2
Juncus marginatus	Rush	FacW	15	1	18
Quercus sp.	Oak	Fac	3	0.05	6.8
Cassia fasiculata	Partridge Pea	FacU	23	0.34	8.2
Carex tribuloides	Sedge	FacW/Obl	5	0.08	4.2
Liquidambar	Sweetgum	Fac	5	0.08	4.2
Total			735	11.74	
Other plants				1.86	
Total Coverage				13.60	
%FacW/Obl		43			

Andalex B

Species	Common Name	Classification	# Individuals	%Coverage	Importance Value
Juncus tenuis	Path Rush	Fac/FacW	179	4.5	74
Artemsia sp.	Tomato-like Plant		50	1.3	29
Cirsium sp.	Thistle	Fac	31	0.8	20
Polygonum sp.	Polygonum	Fac	11	0.3	7
Ranunculus sp.	Buttercup	Fac	15	0.3	14
Rumex crispus	Curly Dock	FacU/FacW	2	0.05	6.6
Scirpus sp.	Sedge	Obl	5	0.13	4.6
Quercus sp.	Oak	Fac	1	0.03	3.4
Allium vineale	Wild Garlic	FacU	12	0.3	10
Total			306	7.71	
Other plants				8.59	
Total Coverage				16.3	
% FacW/Obl		33			

Appendix D

Trees

Sloughs Reference

Tree	# Individuals	Classification	Relative Density	Basal Diameter	Relative Basal Diameter	Importance Value
Willow	1	FacW	0.08	26	0.1	0.3
Black Walnut	5	Upl/FacW	0.42	80.5	0.3	0.99
Cottonwood	1	Fac/Facw	0.08	29	0.11	0.31
Sugar Maple	1	Fac	0.08	22.5	0.08	0.28
Red Oak	1	Fac	0.08	83	0.31	0.51
Dogwood	2	not listed	0.17	13	0.05	0.34
Elm	1	FacW	0.08	12	0.05	0.25
Totals	12	57.14	0.99	266	0.14	

Andalex Reference

Tree	# Individuals	Classification	Relative Density	Basal Diameter	Relative Basal Diameter	Importance Value
Shagbark Hickory	15	FacW/FacU	0.38	325	0.41	1.08
Black Walnut	1	Upl/FacW	0.025	24	0.03	0.095
Red Oak	2	Fac	0.05	46.5	0.06	0.18
Box Elder	8	Fac/FacW	0.2	135	0.17	0.58
Elm	5	FacW	0.125	116	0.15	0.39
Sugar Maple	5	Fac	0.125	62	0.08	0.35
Dogwood	1	not listed	0.025	5	0.006	0.07
Sweetgum	1	Fac/FacW	0.025	34	0.04	0.11
Shellbark Hickory	2	FacW/FacU	0.05	39.5	0.05	0.17
Totals	40	66.67	1.005	787		

Bardstown

Tree	# Individuals	Classification	Relative Density	Basal Diameter(cm)	Relative Basal Diameter	Importance Value
Red Maple	2	Fac	0.5	35.5	0.57	1.57
Sugar Maple	2	Fac	0.5	26.5	0.43	1.43
Totals	4	0	1	62	0.5	1.5

Andalex

Tree	# Individuals	Classification	Relative Density	Basal Diameter(cm)	Relative Basal Diameter	Importance Value
Sycamore	1	Fac/FacW	0.06	18.5	0.08	0.23
Red Maple	2	Fac	0.13	16	0.07	0.38
Sugar Maple	7	Fac	0.44	121.5	0.55	1.27
Cedar	1	Obl	0.06	13.5	0.06	0.21
Elm	3	FacW	0.19	32.5	0.15	0.52
Red Oak	1	Fac	0.06	11.5	0.05	0.2
Hickory	1	FacW/FacU	0.06	5.5	0.03	0.18
Totals	16	57.14	1	219	0.14	0.43

Mill Creek east

Tree	# Individuals	Classification	Relative Density	Basal Diameter(cm)	Relative Basal Diameter	Importance Value
Birch	14	Fac	0.58	145	0.65	1.7
Red Maple	5	Fac	0.21	25.5	0.11	0.62
Sugar Maple	4	Fac	0.17	19.5	0.09	0.36
Willow	1	FacW	0.04	31	0.14	0.28
Totals	24	25	1	221	0.25	

Mill Creek West

Tree	# Individuals	Classification	Relative Density	Basal Diameter(cm)	Relative Basal Diameter	Importance Value
Hickory	2	FacW/FacU	0.13	32	0.09	0.36
Red Oak	1	Fac	0.06	14	0.04	0.17
Birch	3	Fac	0.19	46	0.13	0.53
Red Maple	5	Fac	0.31	155	0.45	0.97
Sassafras	1	not listed	0.06	36	0.1	0.23
Sugar Maple	2	Fac	0.13	16	0.05	0.32
Sweetgum	2	Fac/FacW	0.13	46.5	0.13	0.4
Totals	16	28.57	1.01	345.5	0.14	

Appendix E

Insects

Habitat	Order	Family	Genus	Adult	Nymph	Larvae	Total
	Diptera			55			55
Plants	Homoptera	Aphidae	*A*	30			30
Plants	Homoptera	Aphidae	*B*	4			4
Cosmo	Hymenoptera	Braconidae	*Coeloides*	1			1
Parasitic	Hymenoptera	Bethylidae	*A*	13			13
Cosmo	Hymenoptera	Formicidae	*s.f.Formicina*	3			3
Wet	Homoptera	Cicadellidae	*Draeculacephala*	1			1
Plants	Homoptera	Deltocephalinae	*Circulifer*	1			1
Plants	Homoptera	Cicadellidae	*A*	1	1		2
Plants	Homoptera	Delphacidae	*A*	1			1
Plants	Homoptera	Delphacidae	*B*	3			3
Plants	Hemiptera	Miridae	*Lygus*	3			3
Plants	Orthoptera	Tetrigidae	*A*		10		10
Plants	Collembola	Sminthuridae	*Bourletiella*	1			1
Plants	Coleoptera	Epilachnini	*Epilachna*	1			1
Plants	Coleoptera	Coccinelli	*Hippodamia*	1			1
Gr/Plt	Coleoptera	Carabidae	*A*	2			2
Total							132

Carrollton

Habitat	Order	Family	Genus	Adult	Nymph	Larvae	Total
Plant	Coleoptera	Chrysomelidae	*Odontota*	1			1
Plant	Coleoptera	Chrysomelidae	*Chaetocnema*	1			1
Wet	Homoptera	Cicadellidae	*Draeculacephala*	4	5		9
Plant	Homoptera	Cercopidae	*Lepyronia*	40			40
Plant	Homoptera	Cercopidae			9		9
Plant	Homoptera	Cicadellidae	*A*	6			6
Plant	Homoptera	Cicadellidae	*B*	2			2
Plant	Hemiptera	Rhopalidae			2		2
Plant	Hemiptera	Largidae			1		1
Semi-wet	Coleoptera	Staphylinidae	*Stenus*	1			1
Plant	Hemiptera	Miridae	*A*	1			1
Semi-wet	Coleoptera	Curculionidae	*Hyperodes*	2			2
Plant	Coleoptera	Chrysomelidae	*Epitrix*	1			1
Semi-wet	Coleoptera	Curculionidae	*Stenopelmus*	1			1
Plant	Hymenoptera	Chalicidae	*Metadontra*	1			1
Plant	Hymenoptera	Eurytomidae	*Harmolita*	1			1
Plant	Orthoptera	Gryllacrididae	*Camptonatus*	8			8
Plant	Coleoptera	Nitidulidae	*A*	2			2
Plant	Lepidoptera	Geometridae	*s.f. Oenochrominae*		2		2
Plant	Orthoptera	Gryllidae	*s.f. Nemobiinae*		1		1
Plant	Homoptera	Aphidae	*A*	30			30
Plant	Hemiptera	Coreidae	*A*	1			1
Semi-wet	Collembola	Sminthuridae	*A*	1			1
Semi-wet	Coleoptera	Staphylinidae	*A*	1			1
Plant	Hymenoptera	Pteromalidae	*Habrocytus*	2			2
Plant	Hymenoptera	Braconidae	*A*	2			2
Plant	Hymenoptera	Ceraphronidae	*A*	3			3
	Diptera			79			79
Total							211

Outer Loop

Habitat	Order	Family	Tribe	Genus	Adult	Nymph	Larvae	Total
Wet	Homoptera	Fulgoridae		*Stobaera*	2			2
Plants	Homoptera	Fulgoridae		*Cyrpoptus*	1			1
Plants	Coleoptera	Tenebrionidae			3			3
Plants	Coleoptera	Curculionidae	Ceutorhychini		1			1
Plants	Homoptera	Fulgoridae		*A*	1			1
Gr/Plants	Coleoptera	Carabidae		*A*	2			2
Plants	Coleoptera	Coccinellidae					1	1
Plants	Hymenoptera	Eulophidae		*A*	2			2
Plants	Hymenoptera	Scelionid		*A*	1			1
Plants	Coleoptera	Alticinae		*Chaetocnema*	1			1
Gr/Plants	Coleoptera	Carabidae		*Tachys*	1			1
Aquatic	Coleoptera	Dytiscidae		*Colymbetini*			1	1
Plants	Coleoptera	Curculionidae		*Ceutorhyndinae*	1			1
Cosmo	Collembola	Sminthuridae		*A*	1			1
Gr/Plants	Coleoptera	Carabidae		*Calosoma*	1			1
Plants	Orthoptera	Gryllacridae		*A*	2			2
Plants	Hemiptera	Lygaeidae		*A*	3			3
Plants	Homoptera	Cicadellidae		*A*	5			5
Gr/Plants	Coleoptera	Carabidae		*B*	2			2
Plants	Homoptera	Cicadellidae		*C*	1			1
Wet	Homoptera	Cicadellidae		*Draeculacephala*	5			5
Plants	Homoptera	Cicadellidae		*B*	2			2
Plants	Hemiptera	Saldidae		*Saldula*	1			1
Plants	Coleoptera	Curculionidae		*Odotocorynus*	1			1
Plants	Homoptera	Aphidae			1			1
Wet	Diptera	Tipulidae		*Tipula*			1	1
Wet	Coleoptera						1	1
	Diptera				36			36
	Total							81

Bardstown

Habitat	Order	Family	Genus	Adult	Nymph	Larvae	Total
Wet	Homoptera	Cicadellidae	*Draeculacephala*	8			8
Plants	Neuroptera	Chrysopidae	*Leucochrysa*	1			1
Plants	Hemiptera	Miridae	*Stenodemini*	6			6
Plants	Hemiptera	Reduviidae	*Sinea*	1			1
Plants	Hemiptera	Rhopalidae	*Harmostes*	6			6
Plants	Homoptera	Aphidae	*Theriophis*	16			16
Plants	Homoptera	Aphidae	*Aphis*	4			4
Plants	Homoptera	Aphidae	*Acyrthosiphon*	2		1	3
unknown	Hemiptera				1		1
Plants	Coleoptera	Scolytidae	*Hylurgopinus*	1			1
Plants	Orthoptera	Gryllacrididae	*Camptonotus*	1			1
Plants	Hymenoptera	Braconidae	*Apanteles*	3			3
Wet	Odonata	unrecognizable		1			1
Plants	Coleoptera	Coccinellidae	*Coccinella*			3	3
Plants	Coleoptera	Circulionidae	*Hypera*	1			1
Plants	Aranae	Agelenidae	*Agelenopsis*	2			2
unknown	Lepidoptera					3	3
	Diptera			15			15
Total							76

Mill Creek

Habitat	Order	Family	Genus	Adult	Nymph	Larvae	Total
	Diptera			97			97
Plants	Homoptera	Aphidae		18			18
Wet/Veget	Diptera	Tipulidae		2			2
Wet	Homoptera	Cicadellidae	*Draeculacephala*	5			5
Plants	Hemiptera	Reduviidae	*Sinea*	1			1
Plt/Shb/Wds	Coleoptera	Lycidae	*Calopteron*	3			3
Plants	Hemiptera	Pentatomidae	*Moruidea*	1			1
Gr/Plt	Coleoptera	Carabidae	*A*	1			1
Plants	Coleoptera	Lampyridae	*A*	1			1
Plants	Coleoptera	Carabidae	*B*	1			1
Plants	Coleoptera	Carabidae	*C*	1			1
Plants	Coleoptera	Staphylinidae	*Sepedophilus*	1			1
Plants	Thysanoptera	Thripidae	*Taeniothrips*	1			1
Plants	Hemiptera	Reduviidae	*A*	2			2
Plants	Hemiptera					1	1
Plants	Homoptera					14	14
Woods	Hymenoptera	Sphecidae	*Ampulicini*	1			1
Plants	Hymenoptera	Pteromalidae	*Eupteromalus*	1			1
Plants	Hymenoptera	Ceraphronidae	*A*	1			1
Plants	Hymenoptera	Scelionidae	*A*	1			1
unknown	Coleoptera					16	16
unknown	Arachnidae			10			10
Wet/Bogs	Odonata	Ceonagrionidae	*Amphiagrion*	2			2
Plants	Orthoptera	Gryllidae			2		2
	Orthoptera				1		1
Wet	Coleoptera	Dytiscidae	*Laccophilus*	2			2
Gr/Plt	Coleoptera	Carabidae	*D*	5			5
Plants	Coleoptera	Elateridae	*A*	1			1
Woods	Coleoptera	Curculionidae	*s.f. Scolytidae*	1			1
Plants	Coleoptera	Curculionidae	*A*	1			1

Mill Creek

Plants	Coleoptera	Curculionidae	*B*	2	2
Plants	Coleoptera	Curculionidae	*C*	2	2
Plants	Coleoptera	Curculionidae	*D*	2	2
Plants	Coleoptera	Curculionidae	*E*	5	5
Plants	Homoptera	Cicadellidae	*A*	3	3
Plants	Homoptera	Cicadellidae	*B*	2	2
Total					211

Andalex

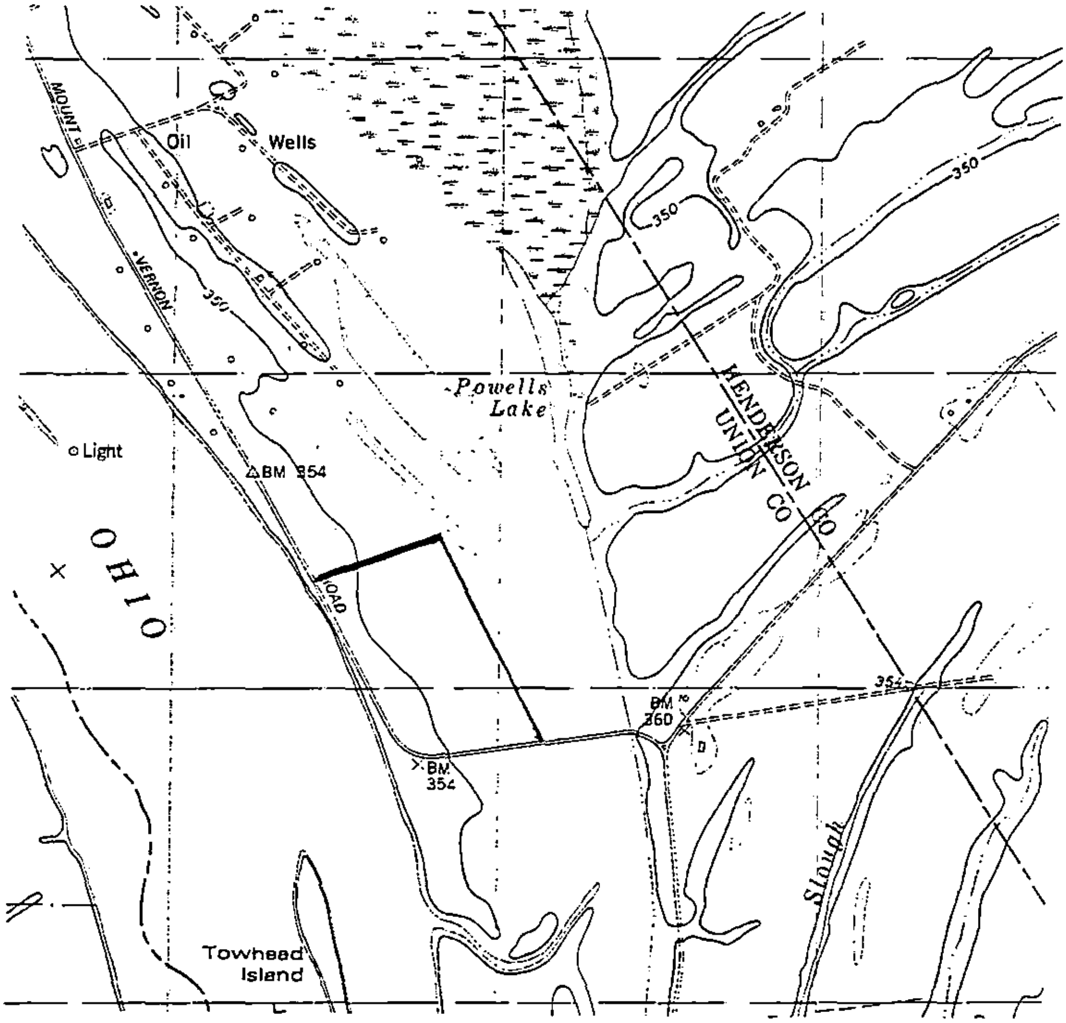
Habitat	Order	Family	Genus	Adult	Nymph	Larvae	Total
	Diptera			85			85
Plants	Homoptera	Aphidae	*A*	9			9
Plants	Hymenoptera	Braconidae	*Apanteles*	1			1
Plants	Hymenoptera	Diapriidae	*s.f. Diapriinae*	1			1
Plants	Hymenoptera	Eurytomidae	*Harmolita*	1			1
Plants	Hymenoptera	Chalicidae	*A*	4			4
Plants	Hymenoptera	Chalicidae	*B*	1			1
Marshes	Odonata	Aeshnidae	*Epiaeschna*	1			1
Fields	Orthoptera	Gryllacridinae	*Camptonatus*	2			2
unknown	Lepidoptera		*A*	1			1
unknown	Lepidoptera		*B*	1			1
Plants	Coleoptera	Coccinellidae	*Hippodamia*			1	1
unknown	Hymenoptera	Mymaridae	*Caraphractus*	2			2
	Arachnidae			2			2
Cosmo	Hymenoptera	Formicidae	*s.f. Formicinae*	1			1
Wet	Homoptera	Cicadellidae	*Draeculacephala*	1			1
Varied	Homoptera	Cicadellidae		10			10
Plants	Hemiptera	Reduviidae	*Sinea*	1			1
Plants	Hemiptera	Reduviidae	*A*	1			1
Plants	Hemiptera	Reduviidae	*B*	1			1
Plants	Hemiptera	Alydidae	*A*	4			4
Plants	Coleoptera					1	1
Plants	Coleoptera					1	1
Total							133

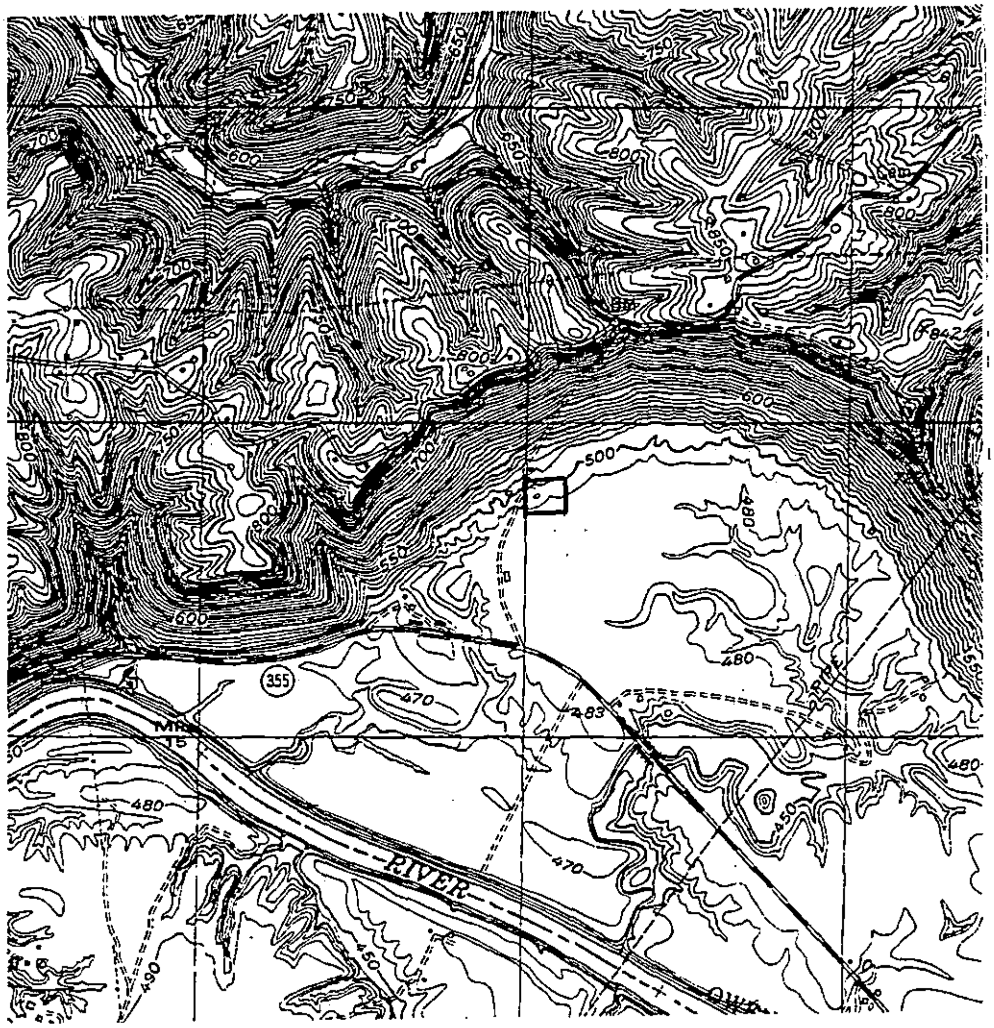
Appendix F

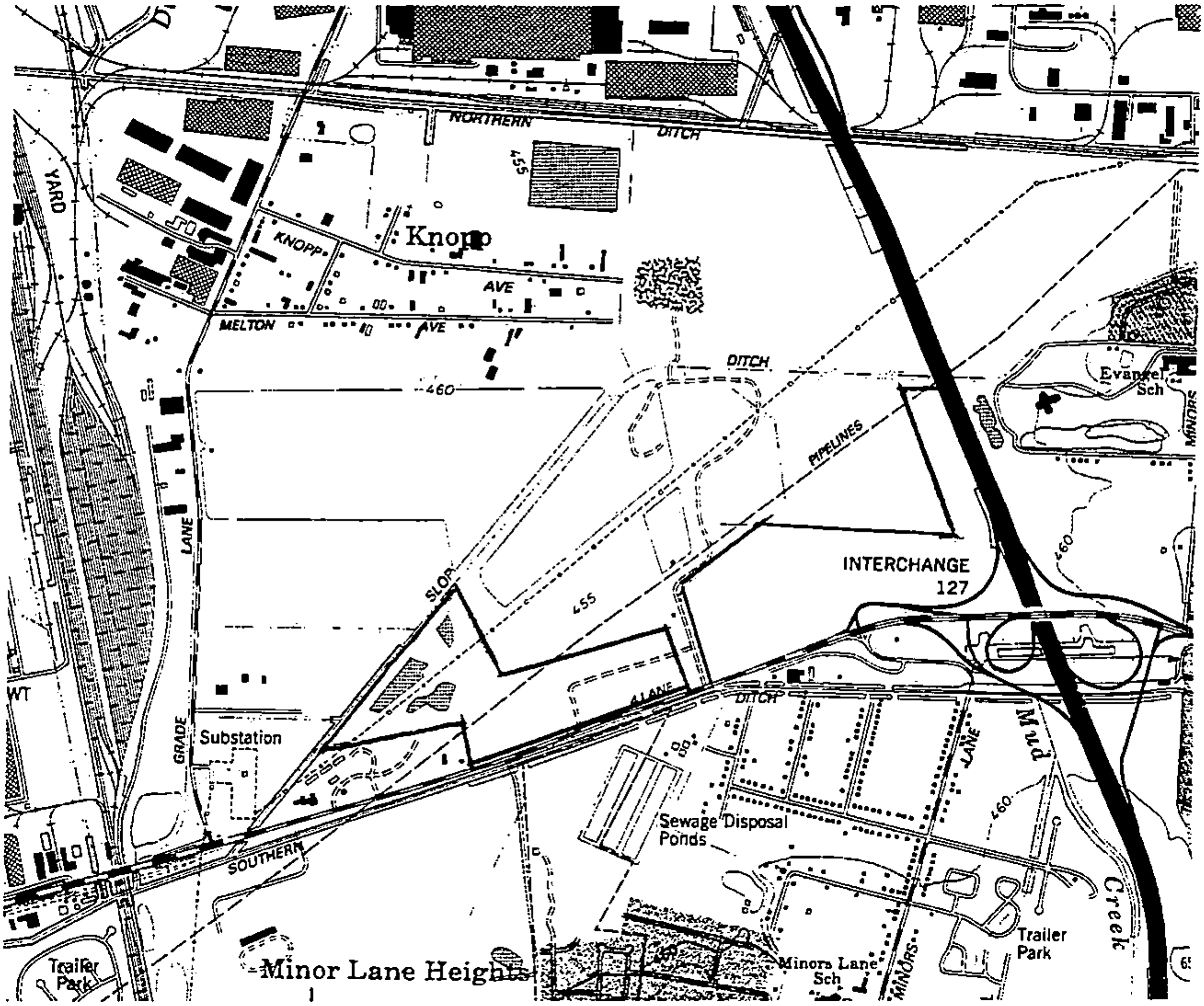
Site Maps

Site Map Order	Quadrangle
Henderson	Uniontown
Carrollton	Worthville
Outer Loop	Louisville East
Bardstown	Lebanon Junction
Mill Creek	Lanesville, IN. and ValleyStation
Andalex	Millport

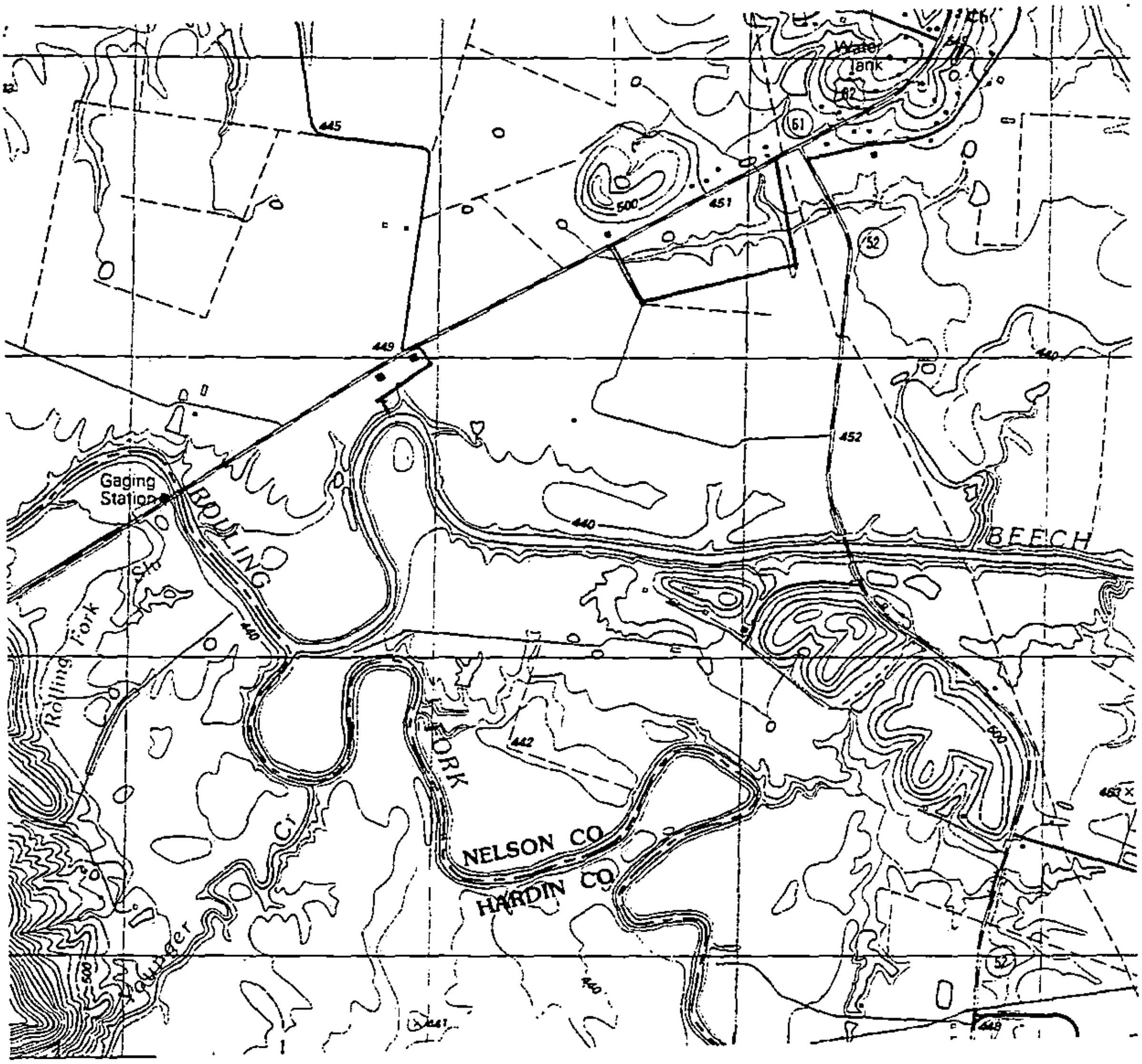
Scale 1:24 000
Contour interval 10 Feet

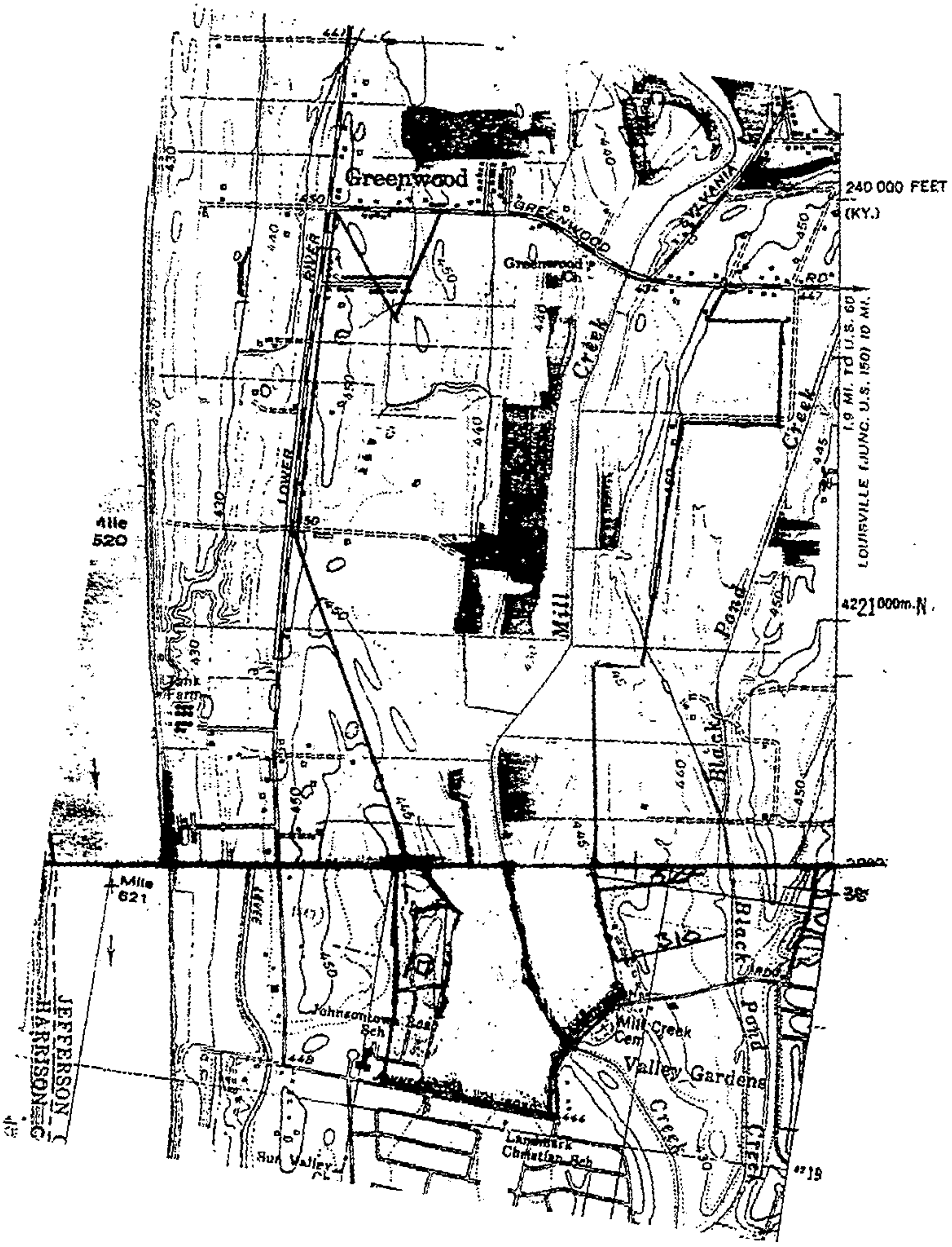

MOUNT
VERNON
ROAD
Oil
Wells
350
350
350
Powells
Lake
HENDERSON CO
UNION CO
Light
BM 354
OHIO
BM
360
BM
354
354
Slough
Towhead
Island

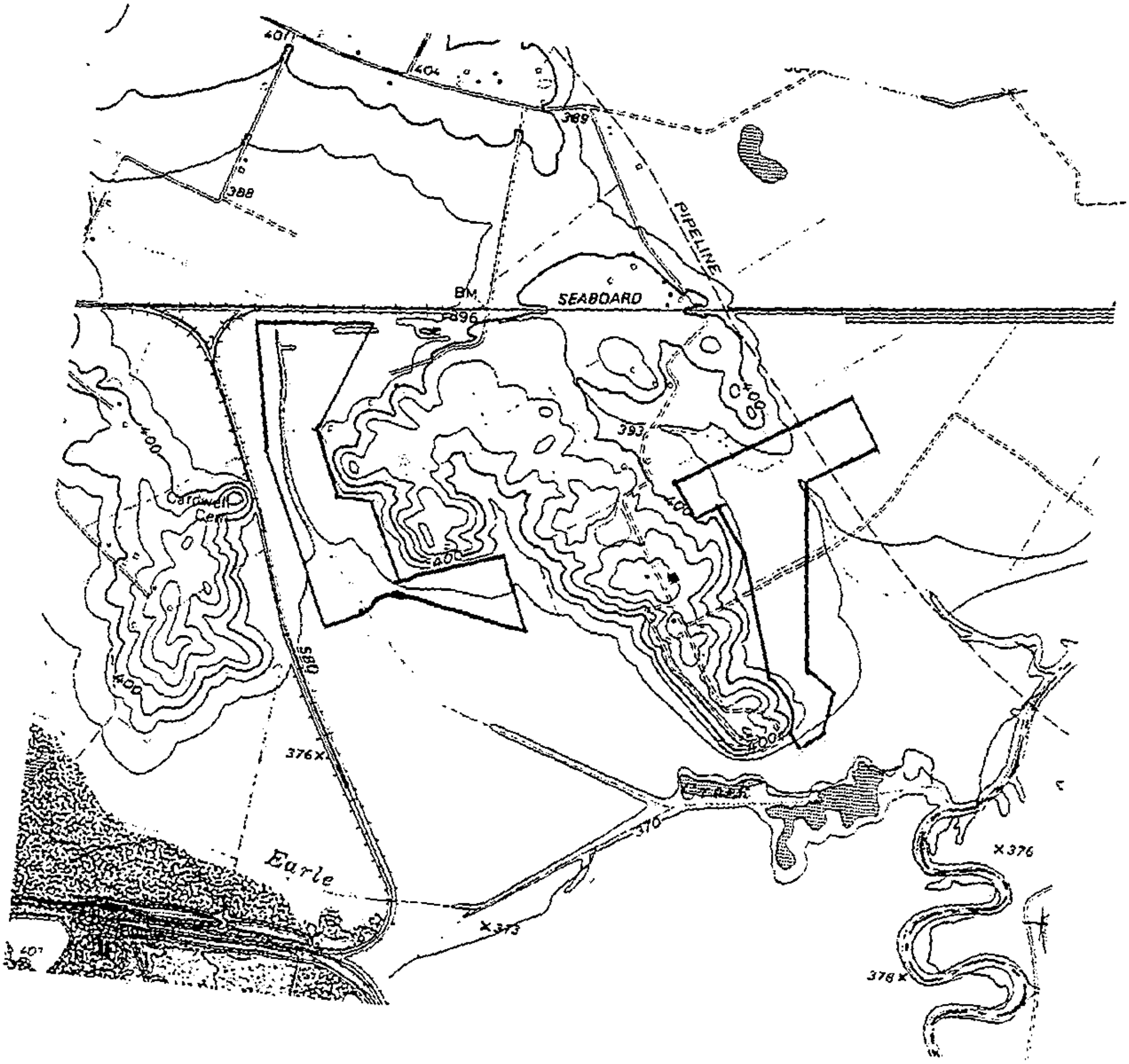

RIVER
355
MR
15
500
550
600
700
800
480
470
483
450
490



YARD
NORTHERN
DITCH
455
Knopp
KNOPP
AVE
MELTON
AVE
DITCH
460
PIPELINES
Evangel
Sch
MINORS
LANE
INTERCHANGE
127
455
SLOP
460
4 LANE
DITCH
GRADE
Substation
Mud
Creek
Sewage Disposal
Ponds
SOUTHERN
460
Trailer
Park
WT
Trailer
Park
Minor Lane Heights
Minors Lane
Sch
MINORS


Water
Tank
Ch
445
500
451
449
452
440
Gaging
Station
ROLLING
BEECH
Rolling Fork
FORK
442
NELSON CO
HARDIN CO
500
441


Greenwood
240 000 FEET
(KY.)
GREENWOOD
RD
Greenwood Ch
Mill
Creek
LOWER
RIVER
Black
Pond
Creek
Big
Mile
520
Mile
621
4221000m.N.
1.9 MI. TO U.S. 60
LOUISVILLE (JUNC. U.S. 150) 10 MI.
Tank Farm
Johnsontown Road Sch
Mill Creek Cem
Valley Gardens
Landmark Christian Sch
Sun Valley Ch
JEFFERSON
HARRISON



PIPELINE
SEABOARD
BM
396
389
388
404
401
393
400
Cardwell Cem
580
376 X
X 373
370
Earle
X 376
378 X